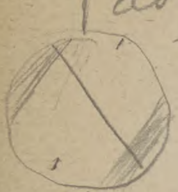
50¢.

C A McGuire

Neutralization
Plus ~~Sph~~ Sph - objects move opposite
Minus Sph " " same direction
Plus Cyl - Direction of axis no movement
other meridian - same direction
as convex. Displaces straight
line away from axis



Plus cyl

Minus Cyl - axis no movement
other meridian - with movement
as in concave lens.

Minus Cyl.
Displaces straight line
toward axis

Neutralize sphero Cyl.
One meridian with sph.
Then other with sph.
or
After sphere neut one meridian
can use cyl for other meridian

ft	meter
200 =	61
100 =	30.5
70 =	21.75
50 =	15.24
40 =	12.19
30 =	9.14
20 =	6.10
15 =	4.57
10 =	3.05

The normal fundus of the right eye examined by the direct method of ophthalmoscopy.

Essentials of Refraction

BY

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PREFACE.

The motif and subject matter of this little book is sheerly and solely refraction. It makes no pretense of being an exhaustive treatise on optics or a text book of diseases of the eye. These departments properly pertain to the eye specialist, for whom this book was not written. But unfortunately they have drawn after them the simpler practice of refraction, and it is this consideration which has led the author to present the essentials of the latter subject in a separate and distinct form.

The science of refraction is based upon a few simple, well-defined principles of optics, easily understood and applied. It is the purpose of this little book to set forth these principles as clearly and concisely as possible, and explain their application to the successful fitting of lenses to the eye. Attention is given solely to those aspects of optics and optical physiology which legitimately concern the refractionist. It aims to impart, in terse and usable form, all that is necessary to the intelligent estimation and correction of refractional errors.

While not purporting to deal with pathological diseases of the eye, it has been thought wise to include a chapter briefly describing those ocular diseases which are intimately connected with

disturbances of vision, and for which therefore the refractionist is frequently first consulted. Thus warned, the refractionist can, by a very reasonable exercise of care, readily detect and identify these conditions, and promptly refer them to the oculist for appropriate treatment.

Special attention is given to the use of the ophthalmoscope and retinoscope. These instruments have for many years enjoyed a deserved popularity among European refractionists in the estimation and correction of refractional errors, and the author believes they are destined to attain equally general favor in this country.

The illustrations are from a series of entirely new and original drawings, designed with a view of elucidating those points which the author's experience has demonstrated to be essential points, most happily demonstrable by means of diagrams, but which unfortunately, are not as a rule made the subjects of illustrations in text books of refraction.

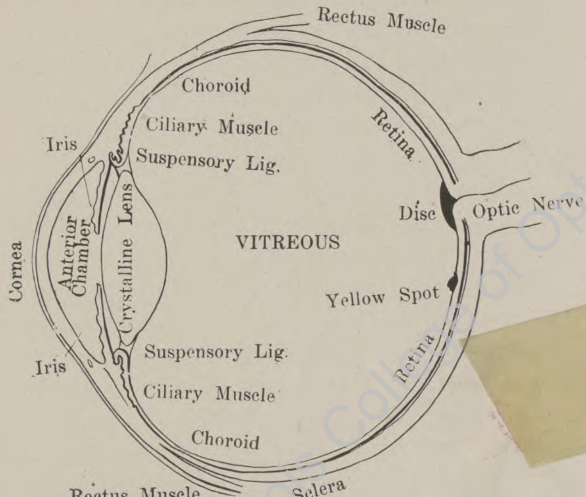
Chicago, June 1906.

CONTENTS.

CHAPTER I.

THE EYE.

For the purposes of this work the eye need be considered only in its capacity as an optical instrument, and insofar as its structure has to do with the phenomenon of refraction and its accessory functions.



Illustrates the anatomic construction of the eye.

The eyeball is formed of the segments of two hollow spheres, of different size and convexity, the smaller and more convex of which

is set into the larger and less convex as a crystal watch glass is let into its case.

The Cornea.—The larger spherical segment consists externally of the **sclera,** which forms five-sixths of the entire eyeball, including all of the posterior portion and that part which is inside the bony orbit. Into the anterior portion of this segment is inserted the smaller segment, the **cornea,** which alone, of the two segments, has to do with refraction.

The Iris.—At the posterior part of the cornea, where it is set into the sclera, inside the globe, is suspended the circular curtain, called the iris, which forms the pupil of the eye, the latter expanding and contracting as the free edge of the iris is drawn up or floated out. It is the pigmentation of the iris which gives color to the pupil.

The Lens.—Immediately behind the iris is the crystalline lens, a double convex lens whose posterior surface is more convex than its anterior, with an elastic capsule, and filled with transparent, colorless fibres.

The Chambers.—The space between the cornea and the iris is called the anterior chamber, and that between the iris and the lens the posterior chamber. (Some anatomists deny the existence of a posterior chamber.)

The Humors.—These chambers communicate with each other, and are filled with a trans-

parent, colorless fluid of a slightly greater density than water, called the aqueous humor. The remainder of the interior of the sphere, comprising four-fifths of the entire globe, is filled with a transparent, jelly-like substance, of about the same refractive density as glass, called the vitreous humor.

The Retina.—Spread out upon the internal posterior surface of the ball is the retina, the sensitive membrane which receives the rays of light, after their passage through the foregoing structures, as an inverted image of the object from which the rays proceeded. .

The eye may, therefore, be regarded as a camera, of which the cornea, crystalline, and vitreous are the lenses, the iris the shutters, and the retina the sensitive plate. The perception and interpretation of the image are functions of the brain, and belong to a study of physiology and neurology.

The Ciliary.—Around the crystalline lens is the circular muscle called the ciliary muscle, and around the extremities of the lens are the suspensory ligaments, which limit the convexity of the lens. These ligaments are held in place by the choroid, the internal lining coat of the sclera. When the ciliary muscle contracts, it draws the choroid forward and releases the suspensory ligaments, whereupon the elasticity of the lens changes its shape to

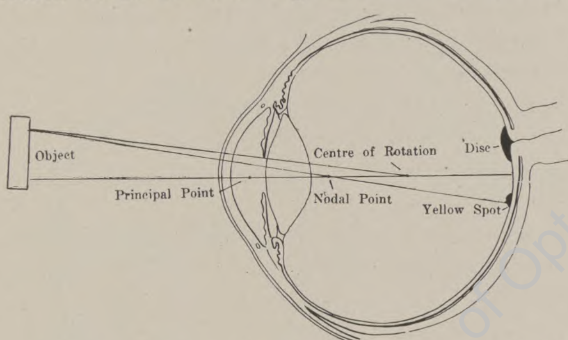
one of greater convexity. This has an important influence upon the refraction of the eye, as will presently be seen.

The Yellow Spot.—Exactly in the centre of the retina, corresponding to the visual axis of the eye, is a small vascular spot, called the macula lutea or yellow spot. This is the spot where the sense of vision is most perfect, and forms the centre of the focussing system. In the centre of the yellow spot is a minute depression, called the fovea centralis, which is the most sensitive point in this sensitive spot.

The Disc.—About an eighth of an inch to the inner side of the yellow spot is the place where the optic nerve enters the retina. This is marked by a slight protuberance, and as it is entirely devoid of sensitiveness it is commonly called the blind spot. In optical language it is also called the disc of the eye, and the fact of its non-sensitiveness is taken advantage of in ophthalmoscopic examination to focus the light upon this point.

Axes.—There are various axes of the eye, i. e., imaginary lines drawn through the eyeball in different directions, and various points situated at different sites on the axes, which are important in the study of the optics of the eye, and they should be carefully studied and thoroughly comprehended by the practitioner of optics.

Since the eyeball consists of segments of two different sized spheres, there are two spherical systems for which to estimate these axes and cardinal points. However, the horizontal axes of the two systems are identical, and the cardinal points of both systems are situated on this horizontal axis. Furthermore, the respective points for the two systems are found to be so near together that for practi-



Shows the various optical axes and points in the eye, also the angles alpha and gamma.

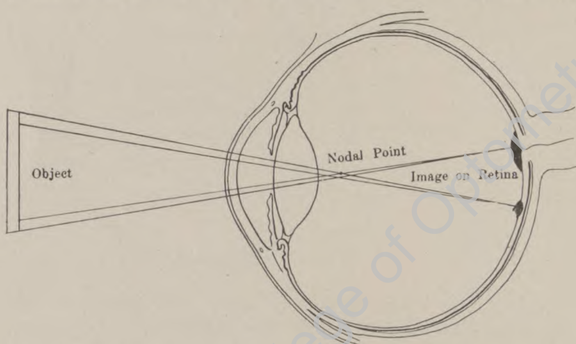
cal purposes they are regarded as being identical.

There are, then, really six cardinal points of the eye, but practically only three. 1. **The principal point**, situated on the horizontal axis two mm. behind the cornea. 2. **The nodal point**, situated on the same axis seven mm. behind the cornea. 3. **The principal focus**,

situated on the same axis where it cuts the retina.

The principal point is the point where the horizontal axis is cut by the mean of the refracting planes (in this case the mean of the curvature of the eye).

The nodal point is the centre of the refracting system, and the axis ray which passes through this point is not refracted. A luminous point placed above the principal (horizontal) axis of the eye forms its image on the



Shows the way in which an inverted image of the object is produced on the retina.

retina below that axis, and vice versa. Hence the retina gets an inverted image of the object from which the rays proceed. The spot at which these planes of rays cross is the nodal point.

The principal focus is that point on the

principal (horizontal) axis where the rays refracted by the combined systems of the eye are brought to a focus. In the normal eye it is of course located at the retina.

The axes of the eye, with which refraction is concerned, are (1) the principal axis, (2) the optic axis, and (3) the visual axis.

The principal axis, as already indicated, is an imaginary line drawn through the centre of the eyeball dividing it horizontally into two equal parts.

The optic axis is an imaginary line drawn through the centre of the cornea and the nodal point to the inner side of the yellow spot. (This is practically identical with the principal axis.)

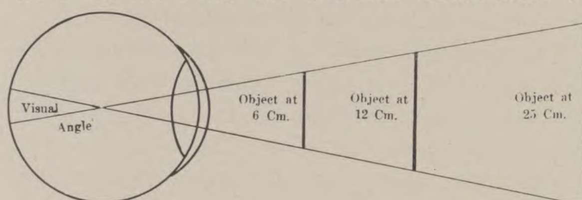
The visual axis is an imaginary line drawn from the object looked at through the nodal point to the yellow spot.

Angle Alpha. — The angle formed at the nodal point by the optic and visual axes is called the angle alpha. In a normal eye it is about 5°.

In addition to the above axes and cardinal points, there are the axes of rotation of the eyeball, imaginary lines around which the eyeball rotates by means of the recti and oblique muscles (these axes are vertical, horizontal and oblique), and the point of the centre of rotation.

Angle Gamma.—The angle made by the visual axis and a line drawn from the object through the centre of rotation is called the angle gamma.

The Visual Angle.—The angle made by two lines drawn from the extreme boundaries of



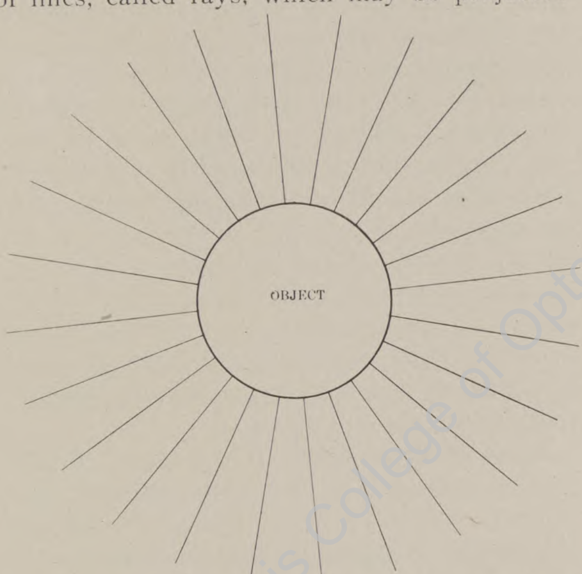
Illustrating the necessity for a larger dimension of order to conform to the visual angle.

the object looked at through the nodal point is called the visual angle. The minimum size of this angle in order that the brain may interpret the image is 1°. That is to say, two luminous points separated by an angular distance of less than 1° would be perceived by the brain as only one luminous point.

CHAPTER II.

REFRACTION.

Optic Rays.—For optical purposes light is considered as being made up of a combination of lines, called rays, which may be projected



Illustrating how rays leave an object in a divergent manner in all directions.

along any plane and in any direction through a suitable medium. As long as they continue to be projected through the same medium they

travel in the same straight line, but upon passing into a denser or rarer medium they are, under certain conditions, deflected or bent from their course.

Finite and Infinite Rays.—Rays of light leaving an object, whether reflected or generated by the object, are projected in a divergent manner, and in all available directions. and doubtless continue to diverge as long as they remain in the same medium, but at a certain distance from their origin the angle of divergence is such that it is impossible to show that they are not parallel, and for optical purposes they are then regarded as parallel. Experience has shown this distance to be six meters or over. Rays, therefore, which originate six meters or more from the observer are said to come from infinity and are regarded as parallel. Rays which proceed from an object less than six meters from the observer are said to be finite, and are divergent.

Laws of Refraction.—When a ray of light passes from one medium into another of a different density, if the surface of the medium into which it passes is perpendicular to the ray, it continues to travel in the same straight line, but at a different rate of speed.

If, however, the surface of the receiving medium is not perpendicular to the path of the ray, the latter, upon entering it, is deflected

from its former course. If it passes into a denser medium the ray is bent toward the perpendicular of the surface, if into a rarer medium it is bent away from the perpendicular.

Spherical Refraction.—When the surface of the refracting medium is spherical, i. e., a section of a sphere, it will be readily seen that only one of a pencil of divergent or parallel rays that enter it will do so at right angles to the surface. This one ray will, therefore, continue its course through the new medium in the same straight line that it had before, and is called the principal axis. All the other rays will be more or less bent (either toward or away from the perpendicular, according to the relative density of the medium) in proportion to the more or less perpendicular at which they strike the surface.

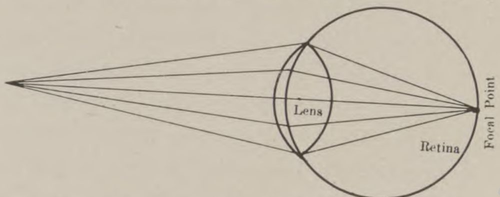
Dense Convex Medium.—When the refracting medium is denser than the outer medium, and its surface a convex sphere, it is mathematically apparent that the refracted rays will all meet at a point.

This point is called the **principal focal point,** and the distance from the circumference to the point is called the **principal focal distance.**

The eye is a refracting instrument of this kind, with a convex spherical surface, of such density as compared with air that, in a normal

eye in a state of rest, parallel rays are exactly focussed on the retina at the back of the eyeball.

Index of Refraction.—The amount of refraction accomplished by a given medium is called its index of refraction. Air is taken as the standard, with an index represented by 1,



Shows how the rays refracted by the eye meet at a point on the retina; i. e., the principal focal point is on the retina.

and that of every other medium is measured by its greater or less power of refraction as compared with that of air at the same obliquity of surface. The index of refraction of water is 1.3.

As a matter of fact the refractive system of the eye is a compound one, made up of three separate media of different densities (the aqeous humor, the vitreous humor, and the lens), and three separate refracting surfaces of different convexities (the surfaces of the cornea, lens, and vitreous). However. for optical purposes it is convenient to regard the eye as a single refractive system, whose con-

of the various parts. This net index of refraction of the eye is about 1.4, but naturally it varies.

Dioptrism.—The refractive mechanism of the eye is called its dioptric system, and the retina, in a normal eye, is situated exactly at the principal focal point of the dioptric system. This condition is called emmetropia; an emmetropic eye is one whose refraction is normal.

Ametropia.—When the retina is not at the principal focal point, but is either beyond or within it, so that parallel rays come to a focus either in front of or behind the retina, the eye is said to be Ametropic. An ametropic eye is one whose refraction is abnormal.

When the retina is situated within the principal focal point, so that parallel rays come to a focus behind the retina, the eye is said to be **Hypermetropic.**

When the retina is situated beyond the principal focal point, so that parallel rays come to focus in front of the retina, the eye is said to be **Myopic.**

When the refracting surface of the eye is irregular, so that all the rays do not focus at one point, the eye is said to be **Astigmatic.**

When the eyes are both ametropic, but differently affected, i. e., when one eye is myopic and the other hypermetropic, or when one is

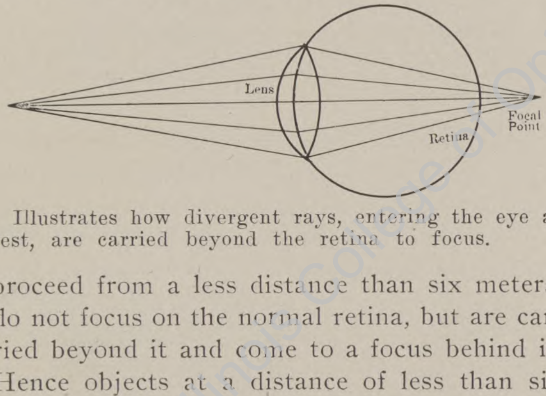
astigmatic and the other spherically aberrated, the condition is called **Anisometropia.** It is highly important in testing refraction to test each eye separately, excluding the other from vision meanwhile.

CHAPTER III.

ACCOMMODATION AND CONVERGENCE.

The Eye at Rest.—When the normal eye is at rest, parallel rays, i. e., rays that originate six meters or more from the observer, are focused on the retina; hence in this condition objects at this distance are, so far as refraction is concerned, clearly seen.

It is evident that under the same condition of refraction divergent rays, i. e., rays that

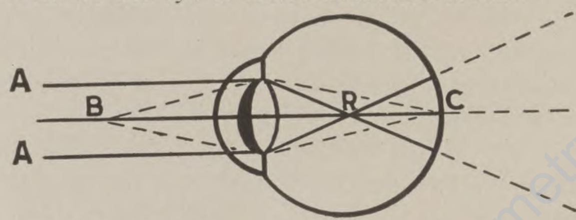


Illustrates how divergent rays, entering the eye at rest, are carried beyond the retina to focus.

proceed from a less distance than six meters, do not focus on the normal retina, but are carried beyond it and come to a focus behind it. Hence objects at a distance of less than six meters are not clearly seen by the normal eye in a state of rest.

Accommodation.—In order that the eye may clearly see objects at a finite distance the re-

fractive power of the eye must be increased. This is accomplished by the contraction of the ciliary muscle, drawing forward the choroid and releasing the suspensory ligament of the lens, whose elasticity then changes its shape so as to increase the convexity of the refracting surface. This power of changing the focus of the eye is called **accommodation.**



Illustrates how the eye accommodates itself to focus divergent rays on the retina. Note the increased convexity of the lens (produced by contraction of the ciliary muscle).

Far Point.—The furthest point at which the eye, with its ciliary muscle completely relaxed, can clearly discern an object whose size corresponds to the visual angle (vide supra) is called its **far point.**

Near Point.—The nearest point at which the eye, with its ciliary muscle contracted to its utmost, can discern an object of appropriate visual dimension, is called its **near point.**

Range of Accommodation.—The distance between the far and near points of an eye is called its **range of accommodation.**

Amplitude of Accommodation.—The muscular and nervous energy necessary to change the eye from its far to its near point **is called** its **amplitude of accommodation.**

The far point of an emmetrope is infinity; that of a hypermetrope is beyond infinity; that of a myope within a finite distance, or less than six meters.

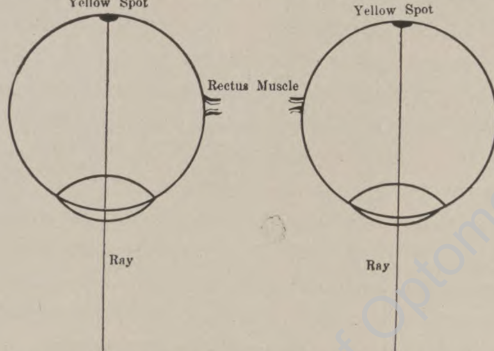
It follows from this that, while an emmetrope can clearly see objects at infinity with no accommodation at all, hypermetropes are obliged to use some of their accommodation even for distant vision. The use of this distance accommodation becomes, after a time, such a habit and the muscle so tetanic, that it can only be measured by complete paralysis of the muscle with atropin. It is called latent hypermetropia; that which is evident without atropin is called manifest hypermetropia.

On the other hand, myopes cannot clearly see objects at infinity at all, because, even when accommodation is completely relaxed, their eyes are still too convex to focus parallel rays on the retina.

Absolute and Binocular.—The amount of accommodation which one eye can exert when the other is shut out of vision is called **absolute accommodation.** That which both eyes together can exert is called **binocular accommodation.** The latter is a little more than the

former, so that in testing for glasses, after testing each eye separately it will usually be found that both eyes together can take a little stronger convex and a little weaker concave correction than each eye separately calls for.

Convergence is a necessary element in near binocular vision, and is, therefore, inti-

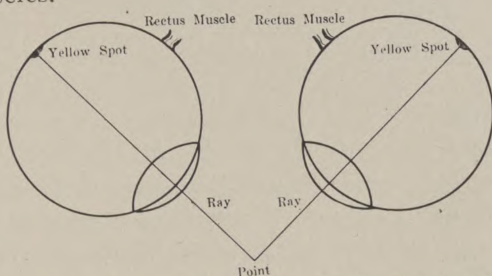


Illustrates how the eyes at rest have their yellow spots adjusted for parallel rays and need no convergence.

mately associated with accommodation. It is, however, quite independent of it, and paralysis of one does not affect the other.

Convergence is the power of directing the visual axis of the two eyes toward a point nearer than infinity. In order to get singleness of binocular vision the image formed on the various parts of the retina must exactly will be double vision. For objects at infinity

the visual axes of the eyes at rest are adjusted to accomplish this; but for objects within a finite distance it is necessary to direct the yellow spot in each eye toward the same point. This is done by converging, i. e., pulling the eyes inward by means of the internal recti muscles.



Illustrates the pulling of the eye inward (convergence) to direct the yellow spots toward the same near point.

Ratio of Convergence and Accommodation.—Convergence and accommodation normally increase and decrease in mutual ratio, since the nearer an object is, the more one has to converge to see it, and the more accommodation one has to use.

It is readily seen, however, that in cases of hypermetropia and myopia this direct ratio is disturbed, the hypermetrope using less convergence and more accommodation, and the myope more convergence and less accommodation.

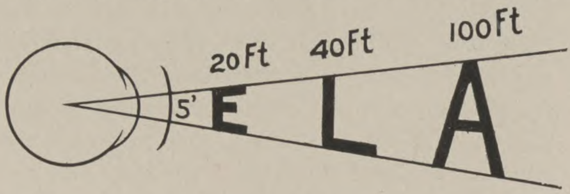
Thus a hypermetrope's far point is beyond infinity, and in order to see an object at six meters he is obliged to use his accommodation, but not his convergence. On the contrary, a myope has his far point nearer than infinity, and in order to see an object at this far point he does not use his accommodation, but is obliged to converge.

The function of convergence and its disturbances do not, per se, come within the province of the refractionist. They only concern him insofar as the paralysis of the converging muscles has been caused by eye-strain due to errors of refraction, and may be relieved by correcting those errors.

Acuteness of vision, while it is quite a distinct thing from refraction, being in fact a function of the nervous visual apparatus, and must never be confounded with refraction, is habitually made use of in testing refraction. The most familiar and useful application of one to the other is the test-type cards that are employed to test distant vision.

Test Types.—These types are constructed on the principle of the visual angle. The visual angle is the angle contained in two lines drawn from the two extremities of the object through the nodal point in the eye. In the normal eye the minimum size of this angle is 1°. Two objects separated by an

angular distance of less than 1° would produce upon the visual center the impression of only one object. On these test cards each



Illustrates the construction of the test type to conform to the visual angle at a given distance. This angle must not be less than 1°.

letter is so constructed that at its proper distance (e. g., No. 6 type at 6 meters) the minimum distance between its parts is not less than 1°.

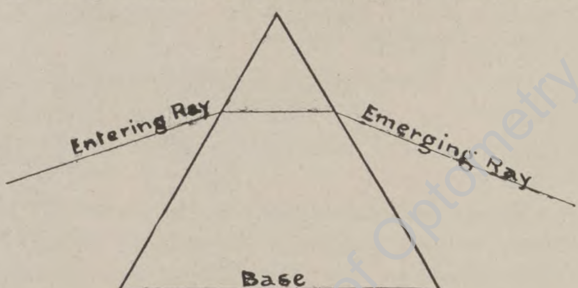
Range of Convergence is the extent of adduction and abduction capable of being accomplished by the internal and external recti respectively. The former is know as positive convergence, the latter as negative convergence.

Amplitude of Convergence is the amount of muscular and nervous energy necessary to change the eye from extreme adduction to extreme abduction, or the reverse, the former being known as amplitude of positive convergence, the latter amplitude of negative convergence.

Prism Tests.—The amplitude of converg-

ence is measured by means of prisms, of which every trial case contains a sufficient supply.

According to the laws of refraction already enunciated, prisms deflect rays of light toward their base, both upon their entering and leaving the medium. Upon striking the surface of the prism, i. e., upon entering a denser medium, the ray is bent toward the perpendicular, which is toward the base. Upon passing out of the prisms into the air again, i. e., upon

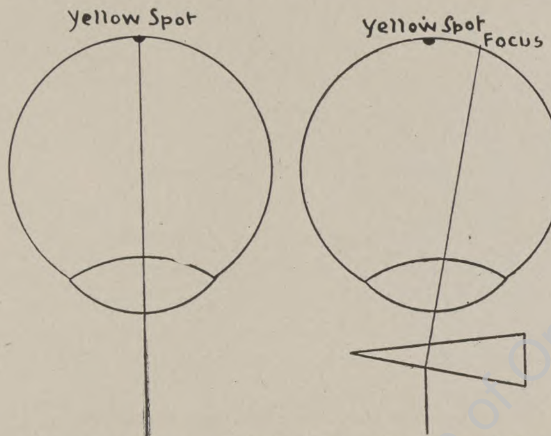


Illustrates how a ray is bent toward the perpendicular both on entering and on emerging from a prism.

entering a rarer medium, it is bent away from the perpendicular, and that is also toward the base.

It will readily appear that a prism placed before the eye with its base outward will focus the image on the outer side of the yellow spot of that eye, while in the uncovered eye the image will fall upon the yellow spot, thus pro-

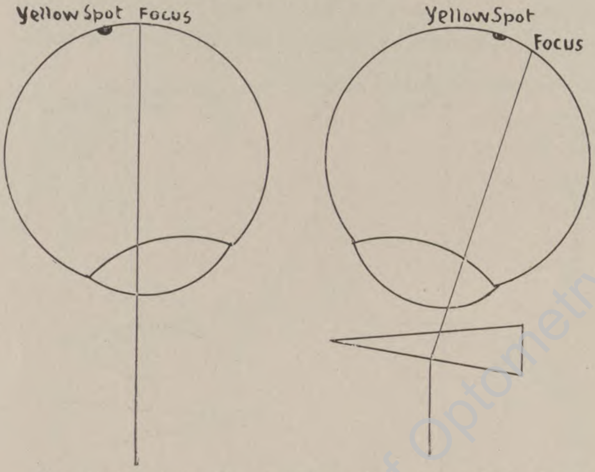
ducing double vision. To overcome this, the internal rectus must contract and pull the eye inward until the images on both retinae coincide as to position. This compensation, however, is not accomplished solely by one eye, inasmuch as one rectus cannot act inde-



Illustrates how a prism, base out, focusses a ray on the outer side of the yellow spot.

pendently of its mate. Therefore, instead of the rectus of the prismed eye pulling that eye inward until the deflected rays focus on its yellow spot, both eyes are pulled inward until the image falls upon corresponding retinal points midway between the yellow spot and that of prismatic deflection, thus dividing the

effect of the prism equally between the two muscles. A prism of given strength held before one eye is equal in effect to two prisms of half that strength held before both eyes.



Illustrates how the compensating correction of the effect of a prism is divided equally between the two eyes.

The same conditions apply to the external muscles under the influence of prisms with their base inward.

Measure of Convergence.—Prisms are numbered according to the degree of their angle, and the angle of the prism which can be overcome by the recti muscles, i. e., the strongest prism with which single vision can be main-

tained is the measure of the amplitude of convergence.

Amplitude of Positive Convergence is measured by the strongest prism, base out, with which single vision can be maintained. A normal pair of eyes should be able to overcome one prism of 20 to 30 deg. or two prisms of 10 to 15 deg. each.

Amplitude of Negative Convergence is measured by the strongest prism, base in, with which single vision can be maintained. Normally the eyes can overcome one prism of 6 to 8 deg. or two of 3 to 4 deg. each.

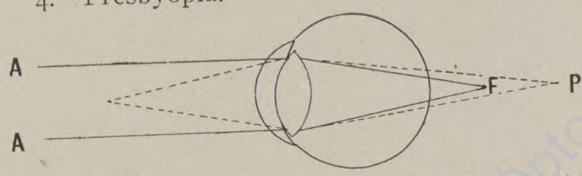
Insufficiency of Convergence.—Anything short of the above-named normal degrees of amplitude indicates weakness or imbalance of the extrinsic ocular muscles, which must be further investigated and dealt with as laid down in the chanpter on that subject.

CHAPTER IV.

ERRORS OF REFRACTION.

The four most common errors of the eye which the refractionist is called upon to correct are:

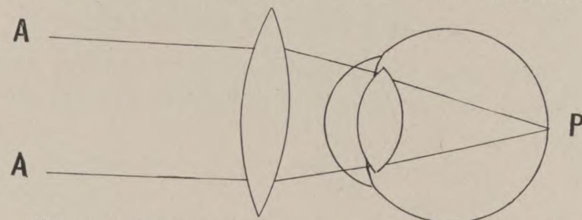
1. Hypermetropia.
2. Myopia.
3. Astigmatism.
4. Presbyopia.



Shows how parallel rays are carried beyond the retina to focus in hypermetropia.

Hypermetropia is that condition of the eye in which parallel rays are focused behind the retina. In other words the antero-posterior diameter of the eye-ball, the distance from the cornea to the retina, is too short in proportion to the refracting power of the eye, and the principal focal point is back of the retina. In order to correct this error the eye has to be furnished with a spherical lens which will increase eye refraction and hasten focusing of all the rays. In other words the refraction of

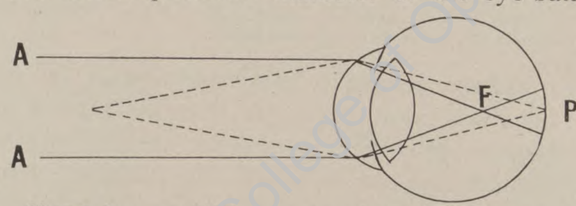
the eye must be assisted by a lens of **the same curvature as the eye itself,** namely, a convex lens. **Convex** lenses are therefore



Shows a hypermetropic eye corrected by a convex lens, which hastens refraction of the rays, and thus brings the focal point forward.

called **plus** lenses, because they add to the refractive power of the eye.

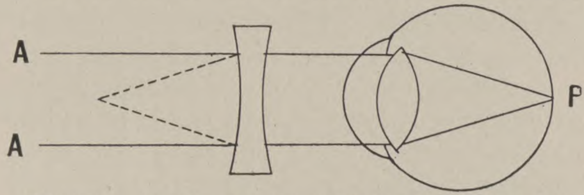
Myopia is that condition of the eye in which parallel rays are focused in front of the retina. The antero-posterior diameter of the eye-ball



Shows how parallel rays are focused too soon, in front of the retina, in myopia.

is too long in proportion to the refractive power of the eye, and the principal focal point is in front of the retina. Its correction requires a spherical lens which will lessen eye refraction and delay focusing of all the rays.

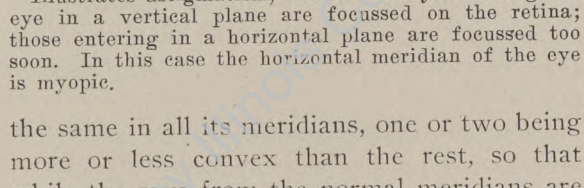
That is to say, the refraction of the eye must be antagonized by a lens of **opposite curvature to that of the eye,** namely, a concave lens. **Concave** lenses are therefore called **minus**



Shows a myopic eye corrected by a concave lens, which delays focussing and thus carries the focal point back.

lenses, because they detract from the refractive power of the eye.

Astigmatism signifies a condition of the eye in which the curvature of the cornea is not



Illustrates astigmatism, where the rays entering the eye in a vertical plane are focussed on the retina; those entering in a horizontal plane are focussed too soon. In this case the horizontal meridian of the eye is myopic.

the same in all its meridians, one or two being more or less convex than the rest, so that while the rays from the normal meridians are properly focused, those from the defective

meridians form a line of unfocused rays, either in front of or behind the retina, and a diffused indistinct image results. As the name implies, it is impossible to focus all the rays at a point.

Chief Meridians.—The most convex and the least convex meridians are always precisely at right angles to each other. If one is vertical the other is horizontal; if one is at 20 the other is at 110. These are called the chief meridians, and are the meridians which must be estimated and corrected.

The eye is normally a little astigmatic, the vertical meridian being naturally a trifle more convex than the horizontal, but as long as the difference is not sufficient to interfere with clear vision it is regarded as normal and not corrected. In pathological astigmatism the relative convexity of the meridians is usually the same as in normal, i. e., the vertical and horizontal meridians are usually the two chief meridians, and the vertical is usually the more convex, and the astigmatism is then said to be "with the rule." But of course there are frequent exceptions to this rule, in which case the astigmatism is said to be "against the rule."

Detection of Astigmatism.—The effect of astigmatism, of course, is an inability to focus that line of rays, out of the group that proceed from an object, which enter the eye at

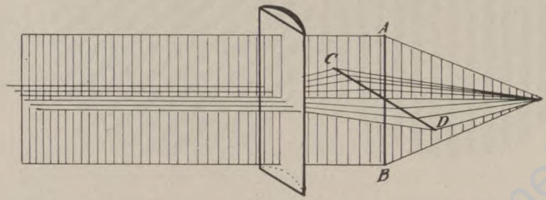
right angles to the defective meridian, the astigmatic meridian behaving toward refracted rays in the same way as a cylindrical lens. Hence the most elementary method of detecting an astigmatism is by testing the

Test figures for detecting astigmatism in four principal meridians.

ability of the eye to discern a series of black lines arranged to correspond with the ocular meridians. They are generally arranged in the form of radiating spokes of a wheel, and found at the top of most makes of test type cards. Dr. Pray's astigmatic letters are con-

structed on the same principle. The line most plainly seen is always at right angles to the defective meridian of the eye.

The correction of astigmatism requires a lens which is a section of a cylinder, convex or concave as may be necessary, its axis being placed at right angles to the defective meridian. By the principles of refraction laid down



Illustrates the correction of the foregoing by a concave cylinder, with its axis at right angles to the defective meridian. The rays entering the cylinder at right angles to its axis are refracted and their focal point carried back to coincide with that of normal meridian.

in Chapter I, rays passing through the cylinder along the plane of its axis strike the surface perpendicularly, and therefore remain unchanged, while those passing through at right angles to the axis are refracted according to the curvature of the cylinder, thus correcting the astigmatic meridian at right angles to the axis.

Astigmatism may be Regular or Irregular. The latter variety, i. e., where several meridians are affected, is so rare that it is unneces-

sary to discuss it here. Regular astigmatism may be:

Simple hypermetropic: Simple myopic.—Where only one meridian is defective, either hypermetropic or myopic.

Compound hypermetropic: Compound myopic.—Where both of the chief meridians are affected in a similar way, either both hypermetropic or both myopic.

Mixed.—Where both of the chief meridians are affected, one being hypermetropic and one myopic.

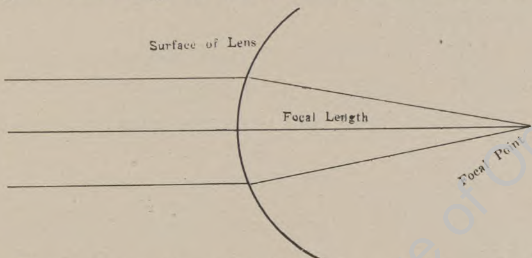
Presbyopia is really a phase of hypermetropia, but the name is used to indicate that form of hypermetropia which depends upon the effects of age upon the crystalline lens, hardening it and thus preventing the ciliary muscle from performing its accommodating function. Presbyopia is arbitrarily said to begin when the patient's near point has receded to 22 cm. This usually occurs at about 45 years of age, and increases about 1 D. for every subsequent five years. Its correction is, of course, accomplished by convex lenses.

CHAPTER V.

LENSES.

Lenses are nowadays usually cut out of crown glass, pebbles being very expensive, hard to grind, and possessing no particular advantages over glass. They are of two kinds as to curvature, convex and concave.

In pursuance of the principle that rays of light entering a denser medium are bent

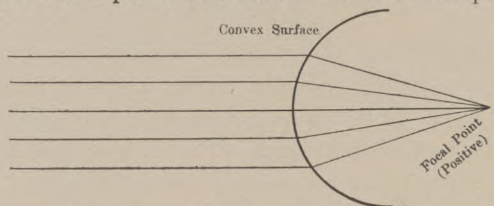


Shows how rays refracted by a convex spherical surface meet at a point. Note that the ray which enters perpendicularly to the surface is not bent.

toward the perpendicular of the refracting surface, rays which enter a convex lens, other than the ray which traverses the principal axis, are bent toward each other, i. e., so as to converge, thus: while those which enter a concave lens, other than along the principal axis, are bent away from each other, i. e., so as to diverge.

The focal point of a lens is the point at which parallel rays, refracted by the lens, are brought to a focus.

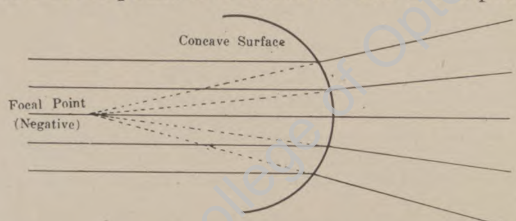
The focal point of a convex lens is the point



Shows how rays entering a convex lens and being bent toward the perpendicular, converge. Note that the focal point is where the refracted rays actually meet (positive).

at which the refracted rays actually come to a focus, F, and is called positive.

The focal point of a concave lens is the point



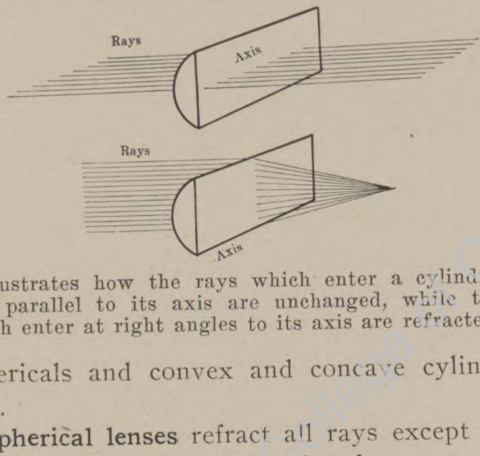
Shows how rays entering a concave lens, and being bent toward the perpendicular, diverge. Note that the focal point is where the refracted rays would meet if projected backward on the concave side of the lens (negative).

projected backward on the concave side of
at which the refracted rays would meet if
the lens, F, and is called negative. This is,

of course, precisely the opposite to the focal point of a convex or concave mirror for reflected rays.

The focal length of a lens is the distance between the refracting surface and the focal point.

Lenses are also **spherical,** i. e., segments of a sphere, and **cylindrical,** i. e., segments of a cylinder. There are convex and concave



Illustrates how the rays which enter a cylindrical lens parallel to its axis are unchanged, while those which enter at right angles to its axis are refracted.

sphericals and convex and concave cylindricals.

Spherical lenses refract all rays except one (the principal axis), and therefore converge them all toward or diverge them all away from a point, the resulting path of the rays being cone-shaped.

Cylindrical lenses refract only those rays which strike them at right angles to their axis; those which strike them in the same line

as their axis are perpendicular to the refracting surface and therefore pass through without any change of direction. Cylindrical lenses therefore converge or diverge a straight line of rays toward or away from a point, the resulting path of the refracted rays being fan-shaped.

Dioptrism.—The refracting power of a lens is called its dipotrism. Inasmuch as the density of the glass is the same in all lenses, this dioptrism is dependent upon the curvature of their surfaces—the greater the convexity or concavity, the greater their dioptrism.

A lens having a focal length of 1 meter, i. e., which brings parallel rays to a focus at a distance of 1 meter from its surface, is taken as a standard, and its strength designated as 1 diopter, or 1 D.

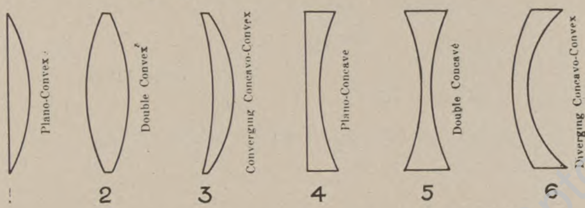
The dioptrism increases in inverse geometrical ratio to the focal length. Manifestly a lens whose focal length is half a meter has twice the curvature, and therefore twice the dioptrism, of one whose focal length is one meter. Therefore a lens whose focal length is half a meter is 2 D, a quarter of a meter 4 D, etc.

The diopter of every lens and its focal length are given in the trial case. The lenses are graded, as a rule, in fractions of 0.25 of a

diopter, which are quite convenient to work with.

Grinding of Lenses.—Spherical lenses are ground in the following manner:

1. **Plano-convex.**
2. **Bi-convex.**
3. **Converging concavo-convex.**
4. **Plano-concave.**
5. **Bi-concave.**
6. **Diverging concavo-convex.**



Shows different method of grinding spherical lenses.

Cylindrical lenses are always ground with the reverse side plano, except when they are combined with spherical lenses for the correction of compound and mixed astigmatism, in which case the spherical correction is ground on the reverse side.

Direction of Movement Plane Mirror

With - Emmetrop - hyperopia or
myopia of less than 1 D

Against - myopia of more than 1 D.

Fast low error:
Faster in one meridian than the
the other. The astigmatism is in
the slow meridian.

"The meridian subtended by the band of
light that is seen when a spheric lens of
1 D or more corrects one meridian and
the meridian at right angles remains
partly corrected, indicates the axis of
the eye in the Rx."

Lens that Neutralizes the shadow
Plus lens when Illumination is with
Minus Lens when " " against

~~Plus Lens~~

CHAPTER VI.

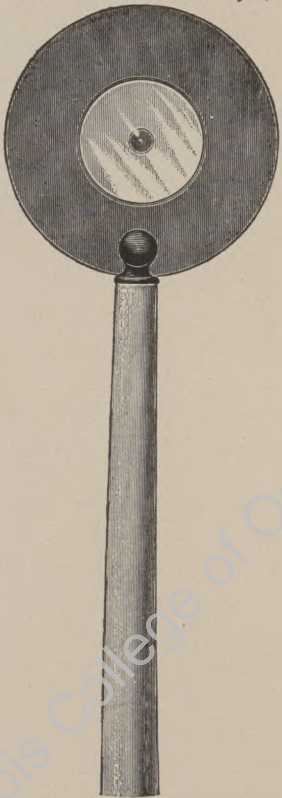
RETINOSCOPY.

Retinoscopy, or the shadow test, is deservedly one of the most popular methods of diagnosing and measuring refractive errors of the eye. It is entirely objective in character, and so is much more reliable in children and nervous individuals. Its technic is extremely simple, requiring only the practice and care necessary to all mechanical manipulations.

The retinoscope itself is a very plain instrument, consisting simply of a round mirror about 3 cm. in diameter, mounted on a stem handle, and having a sight hole through the center of the mirror. There are several different makes of retinoscopes on the market, any one of which is serviceable; but for reasons which are elsewhere explained, it is best to use a concave mirror of 25 cm. focal length.

Atropin.—It is not absolutely essential that atropin be used, but it is always advisable to do so in patients under 30, both because the dilated pupil makes it far easier to observe the results of illumination, and also because complete paralysis of the ciliary muscle prevents its contraction under the bright light and consequent errors in observation. In de-

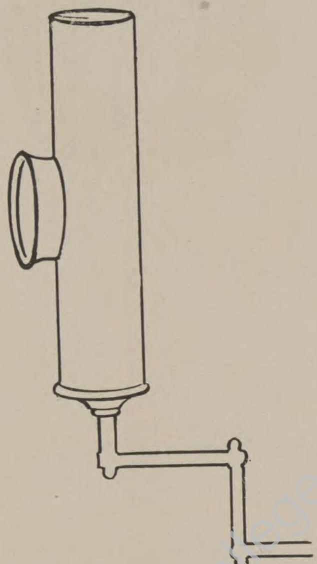
fault of atropin a convex lens of about 1.50 D may be mounted before the eye, but in this



The Retinoscope.

case it must be reckoned with in estimating the refraction.

The examination should take place in a dark room, especially until the operator is practiced and experienced. The best possible light, in the writer's judgment, is an oil lamp with a circular flame and cylindrical glass, but gas

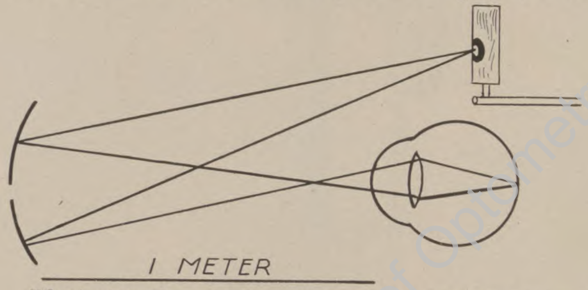


Illustrates the best kind of lamp for retinoscopy.

or electric light will do very well. Whichever light is used, it should have a reflector, or better still, a cylindrical opaque cover with a circular bull's-eye aperture.

The light should be placed above and behind the patient's head, sufficiently low that

no direct rays are thrown on his face, and sufficiently high that it need not be moved in examining both eyes. The observer seats himself or stands about 120 cm. from the patient, and applying his own eye to the sight-hole (at the back of the mirror, of course), throws the reflected light into the patient's pupil. The observer's eye being directly in the path of the rays as they are reflected back from the patient's pupil, the



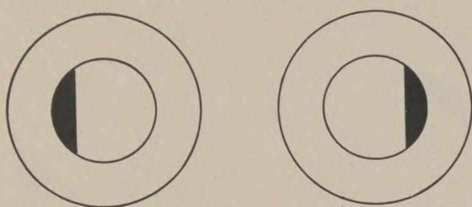
Illustrates the position of the light and the movements of the mirror in retinoscopy.

fundus of the patient's eye is seen as a red glare; this is called the fundus reflex.

Now slightly rotate the mirror with a twirling motion between the finger and thumb, to and fro, on its vertical axis, and the edge of a shadow will appear alternately from each side of the pupil, and move across the illuminated area. This shadow moves either in the same direction as the mirror is rotated, or

in the opposite direction. In technical language, it moves either with or against the mirror. Its edge may be either linear or crescentic, and its direction either vertical or oblique.

If the edge of the shadow be vertical and it move with the mirror (i. e., when the mirror is rotated to the ~~right~~ left the shadow moves to the right), the eye is myopic.



Shows the appearance of the shadows in retinoscopy when their edges are vertical.

If the shadow move ~~against~~ with the mirror, then the eye is hypermetropic, emmetropic, or very slightly myopic.

If the edge of the shadow is oblique and it moves obliquely across the illuminated area, the eye is astigmatic.

The clearer defined the edges of the shadow, and the quicklier it moves across the field, the lower the degree of refractive error. Ill defined, slowly moving shadows indicate a high degree of ametropia.

Myopia.—Suppose then that upon rotating the mirror the shadow is found to move with against the mirror; the case is one of myopia. The patient is instructed to put on the trial frame, a weak concave lens is put up before the eye, and another observation made. If the shadow still moves with the mirror, successively stronger concave lenses are tried, until the shadow is just made to move against the

Shows the appearance of the shadows in retinoscopy when their edges are oblique (astigmatism).

mirror. The weakest concave lens that accomplishes this result is the measure of the myopia and should correct it.

Note how the shadow becomes sharper and moves more rapidly as the correcting lens is more and more nearly approached.

with

Hypermetropia.—Suppose ~~that~~ the shadow is found to move ~~against~~ the mirror; then the case is one of hypermetropia, emmetropia, or very low myopia. If a —0.50 D lens causes the shadow to move with the mirror it is low

against

myopia and may be disregarded. If +1.00 D neutralizes it, the eye is normal. But if with a +1.00 D lens the shadow still moves with against the mirror, the case is one of hypermetropia, and must be corrected in the same manner as myopia, except that in this case we put up stronger and stronger convex lenses, and, instead of stopping at the weakest lens, we continue until we find the strongest convex lens with which the shadow moves against with the mirror.

Astigmatism.—If the shadow moves with unequal celerity on either side, or if its edges are oblique and move obliquely across the field, the case is one of astigmatism; myopic astigmatism if it moves with against the mirror, hypermetropic if it moves against with. The mirror must then be rotated at right angles to each of the two edges separately, one at a time (this being done obliquely if the edges are oblique) and each meridian corrected separately as in myopia and hypermetropia. More detailed instructions for this operation will be found in the chapter on Astigmatism.

Allowance for Atropin.—If atropin has been used in making the tests, 0.75 D should be added to the prescription in hypermetropia and subtracted in myopia, because the ciliary muscle is never quite so completely relaxed as

when it is under atropin. No change need be made in astigmatism.

Allowance for Lens.—If a convex lens has been employed for paralyzing accommodation its strength must be added in hypermetropia and subtracted in myopia.

CHAPTER VII.

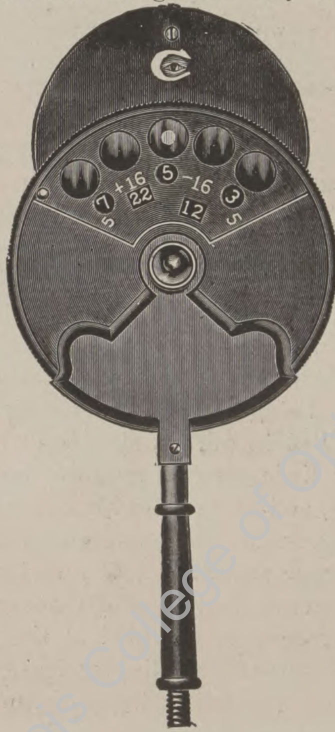
OPHTHALMOSCOPY.

Ophthalmoscopy is considerably more difficult to carry out than retinoscopy, and it is questionable whether as valuable or as accurate information is obtained from it. Nevertheless, it has its place in refraction, and should be practiced in every case, especially as by its means a pathological condition of the eye is often detected which would otherwise escape attention.

The ophthalmoscope is in principle a simple instrument, being essentially nothing more than a small plain mirror, similar to a retinoscope, but a little smaller, mounted on a short stem handle, and provided with a central sight hole. However, the various modern makes of ophthalmoscope are fitted with a series of convex and concave lenses which are made to revolve by means of a wheel at the back of the mirror, so that any diopter lens, plus or minus, can be wheeled in front of the observer's eye, and thus obviate the rather cumbersome necessity of mounting lenses in the spectacle frame during this examination.

For the satisfactory accomplishment of ophthalmoscopy it is almost indispensable to

employ atropin, or a convex lens, for the reflection from the mirror is exceedingly bright (the instrument being held very close to the



The Ophthalmoscope.

eye), and complete relaxation of the accommodation is absolutely essential to correct results.

Ophthalmoscopy is divided into two general methods, the **direct** and **indirect.**

Illustrates method of making direct ophthalmoscopic examination.

Direct Method.—In the direct method, the light, which should be similar to that used in retinoscopy, is placed at the side of the pa-

tient's head, on the same side as the eye to be examined, about on a level with his temple, so that no direct rays fall on his eye. If the operator have any error of refraction he must correct it with proper glasses. The operator seats himself immediately facing the patient, on the same side as the eye under observation, and uses the same relative eye himself. That is, in examining the patient's right eye, he sits on his right side, and uses his own right eye. The observer's unused eye should remain open during the observation.

The operator, holding the mirror about 15 cm. from the patient's eye, and relaxing his own accommodation, applies his eye to the sight hole and throws the reflected light into the patient's pupil. As soon as the red fundus reflex is obtained, the operator, with his eye at the sight hole, gradually approaches the mirror nearer and nearer to the patient's eye, taking care to keep his own accommodation relaxed and to keep the light focused on the patient's pupil, until he is quite close to the patient's eye.

Observation of Fundus.—If the patient's refraction is normal, the details of the fundus, i. e., the blood vessels, etc., should now be plainly seen; for if the patient's eye is completely relaxed, the rays of light leaving it are parallel, and if the observer's eye is similarly

relaxed it is in a position to receive and focus parallel rays, hence the details of the patient's fundus should be plainly pictured on the observer's retina.

Possible Errors.—If at the first attempt the fundus is not clearly seen, the observer should try two or three times, in order to make sure that it is not his own accommodation or his technic at fault. The operation is one which requires considerable practice and cannot be done hurriedly, but the results from a scientific point of view are well worth trying for. Beginners find it especially hard to keep their accommodation relaxed. This can most easily be done by imagining the patient's fundus to be away at the back of his head, and gazing into it with that impression.

Hypermetropia.—When quite convinced that his own technic or accommodation is not at fault, the observer should then wheel a weak convex lens in front of the sight hole and try again. If this helps he should wheel successively stronger convex lenses in front until he gains a clear view of the fundus. This indicates that the patient is hypermetropic, and the strongest convex lens which gives a clear view of the fundus is the measurement and correction of the hypermetropia.

Myopia.—If a weak convex lens makes the fundus still more indistinct, try concave lenses

in front of the sight hole until a clear view is obtained. This means that the patient is myopic, and the weakest concave lens that gives a clear view of his fundus is the measure of his myopia.

Astigmatism.—If, without any correcting lens at the sight hole, the vessels of the fundus are plainly seen in one direction and indistinct or invisible in the opposite direction, this indicates that the eye is astigmatic.

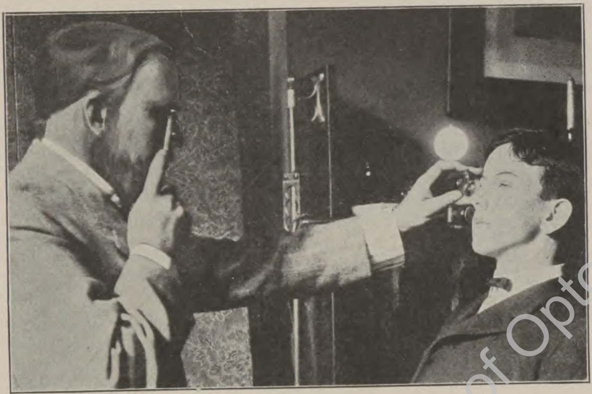
In this case the operator finds the strongest convex or the weakest concave spherical lens which enables him to gain a clear view of the most indistinct meridian, and this spherical lens is the measure of the convex or concave cylinder which will correct the astigmatism.

For reasons already explained, the axis of the correcting cylinder must be placed at right angles to the defective meridian. More detailed instructions for this rather difficult operation will be found in the chapter on astigmatism.

Indirect Method.—The indirect method of ophthalmoscopy is still more difficult of performance and less valuable in data.

The light and general arrangement are the same as in the direct method. In this case, however, the ophthalmoscope, with the observer's eye at the sight hole, is maintained at about 33 cm. from the patient's eye, and the

observer can use the same eye in examining both those of the patient. A strong convex lens is then held by the observer's unoccupied hand close against the patient's eye, in such a way as not to obstruct the light from the lamp to the mirror. One of these strong



Illustrates method of making indirect ophthalmoscopic examination.

convex lenses is included in the ophthalmoscope case, but the writer has usually found it too strong, and prefers a 9 D or 12 D from the trial case.

View of the Disc.—In this method of examination it is not sufficient to get a view of the fundus of the eye. Having thrown the light into the pupil through the strong convex

lens (called the **objective**), and obtained the red fundus reflex, the mirror must be focused so as to reveal the disc of the eye. This requires considerable practice, and can at first only be accomplished by simply shifting the mirror until the disc comes into view. The observer will know when he has focused the disc by the fact that the red fundus reflex will change to a glistening buff color.

This image of the disc (which, being viewed through a convex lens, is a virtual not a real image) must be kept steadily in view and the objective lens slowly withdrawn in a perfectly straight line, away from the patient's eye toward the observer's.

Emmetropia.—If upon withdrawal of the objective the image of the disc remains the same size, the eye is normal.

Hypermetropia.—If the image diminish in size, the eye is hypermetropic. The greater the diminution the higher the degree of hypermetropia. Convex lenses should then be wheeled before the sight hole until the strongest one is found which will cause the image to remain stationary in size on withdrawing the objective. This is the measure of the hypermetropia.

Myopia.—If the image increases in size, the eye is myopic; the greater the increase the higher the degree of myopia. Concave lenses

must then be wheeled before the sight hole until the weakest is found which will neutralize the change in the size of the image. This is the measure and correction of the myopia.

Astigmatism.—If the image increase or diminish in size in one direction only, the eye is astigmatic in the meridian at right angles to the direction in which the image changes. If it diminish the astigmatism is hypermetropic, if it increase it is myopic. And that spherical lens, wheeled before the sight hole, which neutralizes it is the measure of the cylinder which, when placed with its axis at right angles to the defective meridian, will correct the astigmatism.

The carrying out of this method of ophthalmoscopy is exceedingly difficult, and requires long and careful practice. In the writer's judgment it is neither so reliable nor so valuable as retinoscopy.

CHAPTER VIII.

GENERAL PROCEDURE.

Seat the patient in a good light, as nearly as possible six meters from the distance type, using the type-line marked No. 6 as a standard of distance vision.

(N. B. It is not absolutely essential that this distance and type number be observed, as any distance beyond six meters renders the rays parallel. The distance must be at least six meters, and the type-line used as a standard must correspond with the distance. But No. 6 at 6 meters is the generally used standard.)

If a good uniform natural light cannot be obtained, the test card should be illuminated from below wth a good artificial light.

Separate Tests.—Test each eye separately, shutting the other out of vision meanwhile by means of the opaque black disc found in the trial case. It is customary to begin with the right eye.

Make a careful and systematic record of the findings in each test as proceeded with, designating the right eye as R. V. and the left as L. V.

1. **Pin Hole Test.**—Always begin with the

pin-hole test. Instructing the patient to put on the trial spectacle frame, mount before the eye the black disc with the pin-hole in the center which is in every trial case. This has the same effect on the eye as cutting out light from a camera, permitting rays to enter only along its central axis, and should therefore improve the vision of a healthy eye.

If the pin-hole disc does not improve the vision, there is some physical trouble with the eye-ball, and an oculist must be consulted. If it improves the vision, the trouble complained of is an error of refraction and further tests should be proceeded with.

2. **Prismatic Test.**—If your test case contains a chromatic lens, the prismatic test may next be employed with each eye separately.

A white light is placed 6 meters from the patient, and the chromatic lens mounted before his eye.

If the patient sees a blue rim around a central red light, the eye is hypermetropic.

If he sees a red rim around a central blue light, the eye is myopic.

A screen is now placed before the light, with a round opening 6 mm. in diameter immediately in front of the flame, and if the eye is astigmatic the two colors, blue and red, are seen as bars at right angles to each other.

3. **Distance Type.**—The distance type

should now be employed, each eye being tested separately. The patient is directed to look at the type card and tell how far down he can read.

If at a distance of 6 meters he reads type No. 6, his vision is expressed by the fraction 6/6, and is either normal or hypermetropic.

Now mount a weak convex lens, say 0.50 or 0.75 D, before the eye, and if the vision is not blurred by it the eye is hypermetropic, and you may proceed to measure the hypermetropia by the methods described in chapter IX.

If a convex lens does injure the vision, the eye is probably normal and needs only rest and hygienic treatment. But no eye should be dismissed without other tests being made.

If at a distance of 6 meters he cannot read type No. 6, but can read, say No. 4, his vision is expressed by the fraction 4/6, and he is either myopic or astigmatic—perhaps both.

Wheel Test.—Now instruct the patient to look at the fan-wheel which is at the top of the type card, and ask him if all of the spokes of the wheel look equally black to him. If they do, but he is still unable to read No. 6 type at 6 meters, his error is simply myopia, and may be measured and corrected as described in chapter X.

If the spokes of the wheel appear unequally black to him—one intensely black and another

quite faint—he has an astigmatism, and must be dealt with as laid down in chapter XI.

Atropin.—It is always advisable in patients who are under thirty years of age to have the eye under the influence of atropin before beginning to examine them at all. To accomplish this a solution of atropin sulphate, two grains to the ounce, should be prescribed, and the patient instructed to put a drop into each eye three or four times a day for at least two days before the examination. The ciliary muscle is then completely relaxed and the examination can be made with much more accuracy and ease. The patient should, of course, be warned that it will incapacitate him from seeeing clearly for a few days, but it should be pointed out that this temporary inconvenience is more than offset by the accuracy with which his glasses can be fitted to his vision.

In cases where there is objection to atropizing, an attempt may be made to carry out the examination without it, but at the least symptom of spasm of the ciliary muscle (evidenced by erratic statements of the patient as to what he sees, seeing one thing one moment and another the next, and inability to get any results), the test should be stopped and atropin insisted on. It should also be insisted upon whenever astigmatism is suspected, as this

error cannot be properly estimated in young persons without dilatation of the pupil.

Alternatives for Atropin.—In persons over thirty years of age the use of atropin frequently causes diseases of the eye, on account of the tension produced. In these cases where dilatation is desirable it can be accomplished by the use of a solution of hypobromate of hematropin, two grains to the ounce, or a combination of this and five grains of hydrochlorate of cocain. This is to be instilled into the eye, a drop at a time, every ten minutes for two or three hours before examination, and effects pass off in a few hours. This may also be used, if desired, in younger persons, but its relaxing effects are not so complete as atropin.

Convex Lens for Relaxation.—If for any reason neither of the above methods of midriasis are available, a very satisfactory relaxation of accommodation can be obtained by mounting a convex lens before the eye. Usually a 1.50 D or 2.00 D is about right, but the necessary strength varies with the patient. A sufficiently strong diopter should be used completely to paralyze accommodation. When this method is used, the dioptrism of the lens used must of course be added or subtracted from the result of the test, the same as in the case of atropin.

CHAPTER IX.

HYPERMETROPIA.

If the prismatic test gives a red margin around a blue center, and if No. 6 type can be read at six meters and the vision is not injured by a weak convex lens; then the eye is hypermetropic, and the hypermetropia may be measured and corrected as follows:

1. **Distance Type.**—Put up before the eye a convex lens of sufficient strength to over-correct the hypermetropia, and gradually reduce it by putting up concave lenses of increasing strength until No. 6 type can be read. The amount of convex correction then before the eye, after deducting the concave, is the measure of the manifest hypermetropia, and will correct it.

For example, suppose +4 D over-corrects the hypermetropia and blurs the vision. Beginning with —1 D, put up in front of the +4 D lens a series of successively stronger concave lenses until No. 6 can be read at six meters. Suppose that —2 D makes this possible. Then the correction is +4 D less —2 D, that is, +2 D.

This method is far preferable to that of putting up successively stronger convex

lenses, because it first of all completely relaxes accommodation and then gradually encourages contraction of the ciliary muscle. with

2. **Under retinoscopy** (Chapter VI) the shadow moves against the mirror and is not changed by a +1.00 D lens. The quicker the movement of the shadow and the brighter its edges the lower the degree of hypermetropia. The strongest convex lens which makes the shadow move with the mirror is the measure of the trouble and corrects it.

3. **With the ophthalmoscope, direct method** (Chapter VII), the strongest convex lens giving a clear view of the details of the fundus is the measure of the hypermetropia and its correction.

By the **indirect method,** the strongest convex lens under which the size of the image remains stationary on withdrawing the objective is the desired measurement and correction.

Manifest and Latent Hypermetropia.—It will be noted that in describing the type test for hypermetropia it was stated that the result gave the measurement and correction of the manifest hypermetropia. There is always a certain amount of latent hypermetropia, due to the fact that hypermetropes are obliged to use some of their accommodation for long distance visions. This latent hypermetropia is

made manifest by atropin, so that the results under atropin will be found to be about 1 D more than without it. It is advisable to provide for about one-half of this latent hypermetropia in prescribing the glass. Hence if the tests have been made under atropin, about 0.50 should be deducted from the result in prescribing, and if made without atropin 0.50 should be added, in prescribing the glasses.

CHAPTER X.

MYOPIA.

If the prismatic test gives a blue margin around a red center, and if No. 6 type cannot be read at 6 meters but no difference appears in the blackness of the astigmatic wheel, then the eye is myopic, and may be proceeded with accordingly.

Myopia is the simplest to measure and easiest to correct of all the refractive errors of the eye. The degree of myopia present may be estimated as follows:

1. **Distance Type.**—The weakest concave lens which enables the patient to read No. 6 type at 6 meters is the measure of the myopia.

If left to themselves patients will almost invariably choose a concave lens of too great strength. The refractionist must be careful to ascertain the weakest lens with which the type can be deciphered.

2. **Reading Type.**—Give the patient the reading type, and instruct him to move it away from his eyes until the furthest point is reached at which he can read No. 1 type. This is his far point. Measure the distance from the eye to the card in centimeters. This distance divided into 100 (1 meter) will give in

diopters the measure of the myopia present.

For example, if the furthest point at which the type can be read is 25 cm., then 100 divided by 25 is 4. There are 4 D of myopia present, and a —4 D lens will correct it.

against

3. **Under retinoscopy** (Chapter VI) the shadow moves with the mirror. Care must be taken, however, that the observer is further from the patient than his far point, which must be ascertained as directed above. For if the observer is nearer to the eye than its far point it is evident that the rays emerging from the eye have not yet crossed, the image has not been reinverted, and will therefore move against the mirror. For the same reason the observer must be careful to be outside the focal length of the mirror. This can be ensured by using a concave mirror of 25 cm. focus and keeping 120 cm. from the patient. against

Having then attended to these two points, if the shadow move with the mirror the case is certainly one of myopia, and the weakest concave lens which causes the shadow to move against the mirror is the measure of the myopia. with

4. **Under ophthalmoscopy, direct method** (Chapter VII), the weakest concave lens that gives a clear view of the details of the fundus is the measure of the myopia.

By the **indirect method,** the weakest con-

cave lens under which the size of the image remains stationary when withdrawing the objective is the measurement of the myopia.

The foregoing tests, which in simple myopia should all work out the same, also give the diopter of the lens which will correct the error. Thus:

With a —2 D lens the eye can read No. 6 type at 6 meters.

Reading type No. 1 can be read at 50 cm. as furthest point. 100 divided by 50 equals 2.

With a —2 D lens the fundus of the eye can be plainly seen in direct ophthalmoscopy.

Under a —2 D lens, in indirect ophthalmoscopy, the disc remains stationary in size on withdrawing the objective.

Under retinoscopy, a —2 D lens causes the shadow to move against the mirror.

2 D is the measure of the myopia, and a —2 D lens will correct it.

Allowance for Atropin.—If atropin has been used in making the above tests about 0.50 D should be added to the result in prescribing the glasses, because the accommodation is never so completely relaxed as it is under atropin.

Rules for Wearing Glasses.—As a general rule myopes may wear at once their full correction, and should wear their glasses all the

time. To this general rule there are two exceptions.

1. Where the myopia is of high degree the concave glasses diminish the size of the retinal image so much that the patient brings the object close to his eye to make the image larger. In this case the purpose of the glasses defeats itself, and it is wiser to gradually accustom the patient to his correction until his acuteness of vision is sufficiently improved to stand full correction.

2. In cases of high myopia where the patient has got into the habit of converging in excess of his accommodation, full correction, while giving excellent distant vision, may cause him much pain when used for reading, and in this event he must be given full correction for distance and weaker glasses for reading, gradually increasing the strength of the latter until he can bear his full correction for both purposes.

In these cases we subtract from the full correction the lens whose focal length is the same as the distance at which he desires to read. Thus, suppose his full correction is —9 D, and he wishes reading glasses for a distance of 33 cm. A 3 D lens has a focal length of 33 cm. (the focal lengths of the lenses are marked upon the trial cases) and we therefore sub-

tract 3 D from —9 D and give him reading glasses of —6 D.

Hygienic Treatment.—Myopes should be carefully instructed in hygienic measures, even after correction. They should avoid long or strenuous convergence, and frequently rest the eye by looking into the distance. They should read and write in bold letters, with the paper at 33 cm. at least from the eye, and sedulously avoid the stooping posture when reading or writing, which induces congestion of the eye-ball and aggravates the myopia.

Malignant Progessive Myopia.—It should not be forgotten that myopia may be, and frequently is, a progressive and malignant condition, and upon signs of such progression or malignancy a competent oculist should be consulted without delay.

CHAPTER XI.

ASTIGMATISM.

Astigmatism is the most prevalent of the commoner refractive errors, and the most troublesome to estimate and correct.

Prismatic Test.—To carry out the **prismatic test** for astigmatism a white flame is placed behind a screen having a small circular hole, 6 mm. in diameter, immediately in front of the light. The chromatic lens is then mounted before the eye (the other eye being shut off meanwhile) and if the vision is astigmatic the patient, instead of seeing a white circular light, will see two bars of colored light, one red and the other blue, at right angles to each other.

Type Test.—If, in addition to the above evidence, No. 6 type on the distant type card cannot be read at 6 meters, and the spokes of the astigmatic wheel appear unequal in blackness, the eye is astigmatic, and its astigmatism may be measured and corrected as follows:

1. **Wheel Test.**—Instruct the patient to look at the wheel and pick out the spokes that appear the faintest to him. Begin with a weak convex spherical lens and see if it improves

these faint lines. If it does, mount a strong convex spherical lens, as in the measurement of hypermetropia, and gradually reduce it with concave lenses, until the spokes of the wheel which were faintest to the naked eye are clear and distinct. The convex spherical correction necessary to accomplish this is the measure of the convex cylinder which, with its axis at right angles to the defective meridian, will correct the astigmatism.

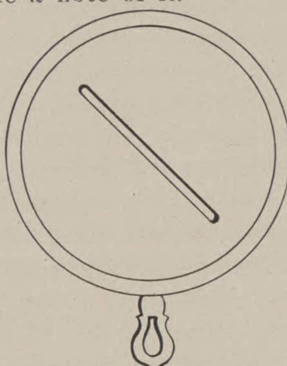
If a convex lens does not improve the weakest lines, but blurs them, then try a concave spherical lens until the weakest is found which brings the faintest lines out clear and black. This lens is the measure of the concave cylinder which, with its axis perpendicular to the defective meridian, will correct the astigmatism.

As this method is applicable only to simple astigmatism, it may be impossible to get any results from it, in which case the observer must proceed to other methods.

2. **Stenopaic Test.**—In the trial case is a Stenopaic Slit, i. e., an opaque disc with a slit in it. Mounting this disc on the trial frame, turn it around until the angle of the slit is found which gives the patient the best possible vision of the distant type. If this vision is 6/6, the refraction of the patient's best meridian is normal, and he has a case of

simple astigmatism. If, at this best angle, he is unable to read No. 6, find the spherical lens which, placed in front of the slit, will give him 6/6 vision, and make a memorandum of it.

Now turn the slit exactly at right angles to its best position. This gives the eye its worst vision. Again find the spherical lens (either convex or concave) enabling him to read No. 6, and make a note of it.



The Stenopaic Slit for Detecting and Diagnosing Astigmatism.

Simple Astigmatism.—If with the slit at its best angle no lens was necessary to make the vision 6/6, then only one meridian of the eye is astigmatic (simple astigmatism). The spherical lens required to make vision 6/6 with the slit at its worst angle is the measure of the cylindrical lens which will exactly correct the astigmatism. **The cylinder must be**

prescribed with its axis perpendicular to the slit.

Example: The slit at 90° (vertical) gives best possible vision, and this vision is 6/6. At 180° it gives worst vision, and +2 D. spherical raises this vision to 6/6. Then +2 D. cylinder, axis at 90°, will correct the astigmatism.

Compound Astigmatism.—If, however, a lens was needed to make the vision 6/6 with the slit at its best angle, then both of the meridians of the eye are astigmatic (compound astigmatism). If the lenses required to correct the best and worst meridian are of the same curvature (i. e., both plus or both minus) the astigmatism is a compound hypermetropic or compound myopic astigmatism, as the case may be.

In this case the strength of the spherical lens used to correct the best meridian (i. e., with the slit at its best angle) should be prescribed as a cylinder with its axis at right angles to the slit. This really corrects the astigmatism, and reduces the error to simple hypermetropia or myopia, as the case may be, equal to the difference between the two meridians. We therefore prescribe this difference as a spherical correction, in combination with the cylinder.

Example: The slit at 90° (vertical) gives

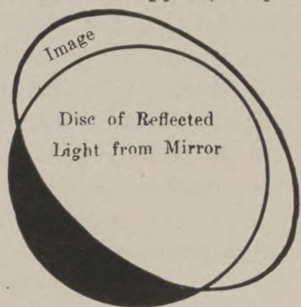
best possible vision, but this vision is not 6/6, and requires +1 D. spherical to make it normal. At 180°, the worst angle, it requires +2.50 D. spherical to make vision 6/6. Then a +1 D. cylinder, axis at 180°, will correct the astigmatism, and the spherical lens of 1.50 (i. e., the difference between the two meridians) will correct the remaining hypermetropia. With minus lenses the results would work out precisely the same.

Mixed Astigmatism.—If the lenses required to correct the two meridians are different in curvature (i. e., one plus and the other minus), the astigmatism is a mixed one. In this case the spherical lens used to correct the best meridian should be prescribed as a cylinder with its axis at right angles to the slit. This really corrects the astigmatism, and reduces the error to a simple hypermetropia or myopia, as the case may be, equal to the sum of the two meridians. We therefore prescribe this sum as a spherical correction in combination with the cylinder.

Example: The slit at 90° (vertical) gives the best possible vision, but this vision is not 6/6, and it requires +1 D. spherical to make it normal. At 180° it requires —2.50 D. to make vision 6/6. Then a +1 D. cylinder, axis at 180°, will correct the astigmatism, and a spherical lens of —3.50 D. (i. e., the sum of

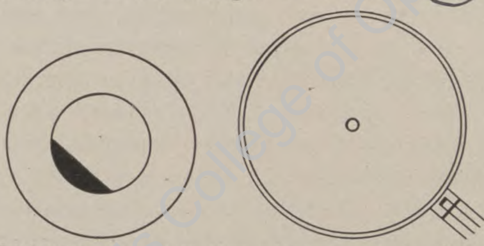
the two meridians) will correct the remaining myopia.

3. **Under retinoscopy** (Chapter VI) the



Illustrating why the shadow in retinoscopy is oblique in astigmatism; viz., because the image is oval shaped.

edges of the shadow are usually oblique, and move obliquely. This is on account of the oval shape of the image. If it move with the against



Illustrates the way the mirror must be held and rotated when the shadow is oblique, namely, perpendicular to the edge of the shadow.

mirror, the astigmatism is myopic; if it move against, it is hypermetropic. with

Sometimes, however, the edges of the

shadow are vertical, and move horizontally, and the only way we are led to suspect astigmatism is because one edge is more distinct or moves more quickly than the other.

In either case, the mirror must be rotated at right angles to the edge of the shadow (obliquely if the shadow is oblique, horizontally if the shadow is vertical), and the two chief meridians corrected one at a time. with

For example: We find the shadow vertical, and moving against the mirror. We first test the vertical meridian, rotating the mirror horizontally, and find the strongest convex lens against which causes the shadow to move with the mirror. Suppose this is found to be +2 D. We then test the horizontal meridian, rotating the mirror vertically, and find the strongest convex lens which makes the shadow move against with the mirror is +2 D. We know that the meridians are the same and the case is one of simple hypermetropia.

Suppose, however, in testing the horizontal meridian we had found that +4 D was the against strongest convex lens making the shadow move with the mirror. Then we have a compound hypermetropic astigmatism, 2 D in the vertical meridan and 4 D in the horizontal, needing for its correction +2 D cylinder, axis horizontal, and +2 D spherical (i. e., the difference between the two meridians).

Where the shadow is oblique, we know at once that astigmatism exists, and proceed to estimate it as above, only in this case we rotate the mirror at right angles to the edge of the shadow and then parallel to it, and the axis of the correcting cylinder is placed accordingly. Thus, if the edge of the shadow is tilted at 20° the cylinder is prescribed with its axis at 110°, which is precisely at right angles thereto.

Retinoscopy is a very useful and rapid means of estimating and correcting astigmatism with experienced refractionists, who are usually able to do it by this method with great accuracy. But beginners will find it somewhat difficult, and no one should ever rely on it without confirmation by some other method.

4. **Under ophthalmoscopy, direct method,** (Chapter VII), the plan is to find the spherical lens, convex or concave, which affords a clear view of the principal meridians, testing one at a time.

By the **indirect method** the disc is oval instead of circular, and increases or decreases in one direction more than another on withdrawing the objective. The spherical lens, convex or concave, which corrects this is the measure of the astigmatism in each meridian,

which must then be corrected as already described.

This method of estimating astigmatism, however, is so difficult and untrustworthy that it is of value only from a scientific point of view and is not recommended for any other purpose.

The stenopaic slit will generally be found, in ordinary cases, the most serviceable and practicable method of working out astigmatism, and the author strongly commends it to his readers as superior to all others. All findings should, however, be confirmed by all the means at one's command.

CHAPTER XII.

STRABISMUS. (SQUINT.)

Strabismus is that condition of the eyes in which the yellow spots are not directed toward the same point in the object viewed. When the lines along which they are directed diverge from one another, the condition is called divergent strabismus; when they converge toward each other, it is called convergent strabismus. In both cases there is double vision; in the latter variety there is direct double vision, i. e., the image seen by each eye appears to be on the same side as the eye perceiving it. In the former variety there is crossed double vision, i. e., the image seen by each eye appears to be on the opposite side from the eye which perceives it. This is easily diagnosed by mounting a colored glass before one eye and observing which image appears colored.

Strabismus is real or apparent.

Apparent strabismus is the effect of a disturbance in the relationship between the optic and visual axes, due to hypermetropia or myopia. The optic axis is a line drawn through the nodal point of the eye to the center of the cornea; the visual axis is a line drawn

from the object viewed through the nodal point to the yellow spot. The angle made by these two lines is called the angle alpha, and in the normal eye is about 5°.

The Angle Alpha.—In myopia the nodal point is relatively further back than in the normal eye, and the angle alpha is thereby enlarged. This, by a confusion of judgment in the observer between the optic and visual axes, gives the patient the appearance of having a divergent strabismus. In hypermetropia the nodal point is relatively further forward than normal, and the angle alpha is diminished, sometimes completely obliterated, and occasionally the two axes cross, in which case the angle alpha is said to be negative. This gives the patient the appearance of having a convergent strabismus.

It is of course highly important to be able to determine whether a given case of strabismus is real or apparent, and fortunately this is very easily ascertained. We simply hold an object, such as a pencil, about a meter from the patient's eyes, directing him to keep looking at it, and gradually move it nearer to his eyes. If both visual axes continue to be directed toward the object the case is one of apparent strabismus. But if during the experiment one eye suddenly deviates, either inward or outward, then we have a case of real

strabismus, which must then be diagnosed by further means.

Real strabismus is due to a defect in the function of the recti muscles of the eye, and may be generally classified into **Concomitant** and **Paralytic strabismus.** Properly speaking, these two varieties are but different degrees of the same trouble, but for practical purposes we recognize as concomitant strabismus those cases in which the deviation of the squinting eye is constant, and its range of motion is practically equal to that of the sound eye, while by paralytic strabismus we understand a condition in which the paralysis of the recti is such as to seriously interfere with motion of the deviating eye.

Diagnosis of Strabismus.—In some cases it is possible to determine roughly between concomitant and paralytic strabismus, by simply having the patient follow with his eyes a small object moved in various directions, and observing whether or not the deviating eye follows the motions of the sound one. But this is not at all a reliable test. The only trustworthy way of diagnosing the nature of the squint is as follows:

First instructing the patient to look straight in front of him, make a mark on the lower eyelid with a piece of crayon indicating the position of the pupillary center in each eye.

Now cover one eye in such a manner as to obstruct the patient's view, but so that the observer can watch the movements of the covered eye. Instruct the patient to look steadily with his uncovered eye at a small object held a short distance from him. (This is called "fixing" the object.) The covered eye will be seen to make a sudden movement inward or outward, and the extent of this movement should be indicated by another chalk mark on the eyelid.

Now cover the other eye and repeat the experiment. If the deviating movements made by the two eyes, as indicated by the chalk marks, are equal, the strabismus is concomitant. If one eye made a greater deviation than the other, the strabismus is paralytic, and that eye which made the greater deviation is the sound eye.

The deviation made by the squinting eye in this experiment is called the **primary deviation,** that made by the sound eye the **secondary deviation,** and the law is that in concomitant strabismus the primary and secondary deviations are equal; while in paralytic strabismus the secondary deviation is greater than the primary.

Paralytic strabismus is of course a matter for the neurologist to deal with, and need not be considered in a work on optics. By far the

greater proportion of cases of concomitant strabismus, however, are due to errors of refraction, high degrees of hypermetropia or myopia, and are therefore legitimate subjects for the optician.

Treatment of Strabismus.—In recent cases, and in cases of what is called periodic strabismus, i. e., where the squint appears only under the strain of near vision or at times of great bodily fatigue, the proper correction of the refractive error and resting the eyes from near work is often sufficient to effect a cure. In more permanent cases it is frequently necessary to give the patient prolonged rest for his eyes by means of atropin, say three or four weeks.

In divergent strabismus much good may sometimes be accomplished by orthoptic exercises by means of prisms, for particulars of which, however, a larger work must be consulted. Such treatment requires great patience and judgment, and should not be carried out by one who does not thoroughly understand the anatomy and physiology of the matter. For convergent strabismus no exercises of this kind are serviceable, as there is no known means of exciting the external recti to contraction.

If none of these expedients succeed the case becomes one for the ocular surgeon.

CHAPTER XIII.

MUSCULAR IMBALANCE.

Of much more frequent occurrence than actual strabismus is the condition of latent deviation known as muscular imbalance, or heterophoria, in which one of the extrinsic muscles of the eye has, from some cause or other, become less efficient than its antagonist, necessitating an excessive innervation of the weaker muscle in order to prevent deviation, and giving rise to what is known as **eye-strain,** with occasional lapses into periodic strabismus.

Varieties of Heterophoria.—According to the direction in which the eye tends to deviate, heterophoria has been divided into three general classes, dependent, of course, upon insufficiency of the muscle acting in the opposite direction, as follows:

Variety	Tendency	Faulty Muscle
Exophoria	Outward	Internal Rectus
Esophoria	Inward	External Rectus
Hyperophoria	Upward	Obliques.

Inasmuch, however, as this classification involves an inversion of the nomenclature of the condition and the muscle at fault, it is not a very convenient one, and the writer much prefers Gould's method of designating the

trouble by the term "imbalance" of the muscle in question.

Of the above varieties of imbalance the last is so rare that it will be disregarded in the present work.

Causes of Imbalance.—The muscular insufficiency may be due to a general lack of muscular or nervous tone, whose underlying cause is to be found in some constitutional disease, such as tuberculosis, syphilis, anemia, neurasthenia, etc. Far more commonly, however, it is a result of long-continued error of refraction, involving an extraordinary disturbance of the normal relations between accommodation and convergence. In fact, every condition of ametropia inevitably and logically produces muscular imbalance, and it is simply a question of the degree in which it exists, ranging all the way from imperceptible heterophoria to actual strabismus.

Rationale of Refractive Imbalance.—It has already been explained that, while accommodation and convergence are anatomically distinct and separate functions, they are very intimately associated, and the exercise of one is a powerful stimulus to the performance of the other. Hence when, as in hypermetropia or myopia, the normal relation between the two functions is disturbed by the abnormal conditions of accommodation, the natural tend-

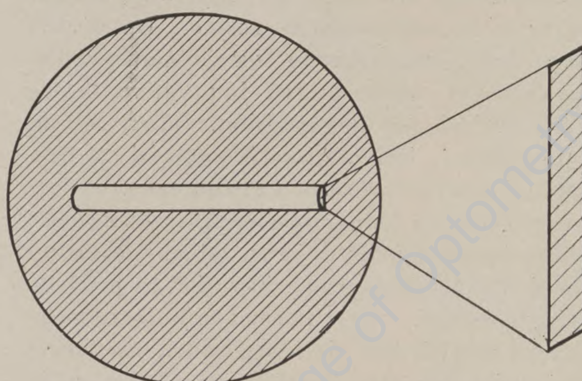
ency of convergence is to follow suit, and it is only prevented from doing so by an excessive innervation of the muscle concerned in such prevention.

Thus, a hypermetrope, as we have seen, is obliged to use his accommodation for objects at infinity, and when he does so the natural tendency of the internal recti is to contract and converge the eyes in proportion to the degree of accommodation exerted. But if this were done, convergence for distant vision would result, whereas the imperative desire of the brain is for single vision. Therefore an extraordinary innervation is applied to the external recti to prevent convergence.

A myope, on the other hand, does not accommodate for near objects, which nevertheless demand convergence in order to produce a single image. The normal stimulus to the internal recti is here lacking, and the external recti are naturally stimulated to contract in correspondence with the negative accommodation. An excessive innervation is therefore necessary to bring the internal recti into adequate play.

Muscular Failure.—In both of these conditions, if long continued and the eyes constantly used, the overworked muscle eventually becomes weakened, and there is a latent deviation toward the direction of its antagonist,

which is only prevented by an increasing conscious effort which at times (especially under strain of bodily fatigue) fails, and temporary strabismus occurs. In hypermetropic imbalance (by far the commonest type) it is the external recti that suffer and the tendency is to convergence; in myopic imbalance the internal recti are overworked, and the tendency is to divergence.

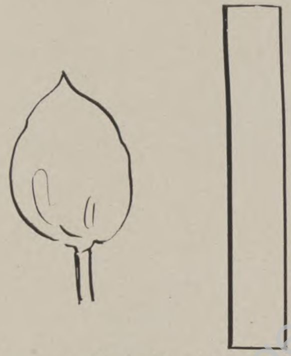


Illustrates the Maddox rod, and shows how it produces a bar of light at right angles to its axis.

Distinction Between Imbalance and Strabismus.—Eventually, of course, imbalance, if not relieved, will end in strabismus, which is functionally only an intenser degree of heterophoria. The practical difference between the two conditions is that in imbalance the brain is, by an effort, maintaining single vision at

the expense of the muscle, whereas in strabismus the muscle is no longer able to maintain proper poise; single vision is then impossible, therefore the brain has ceased to strive for it, but fixes the object with one eye or the other, disregarding the image on the unused eye.

Tests for Imbalance.—These are, in the gross, the same as those already given for



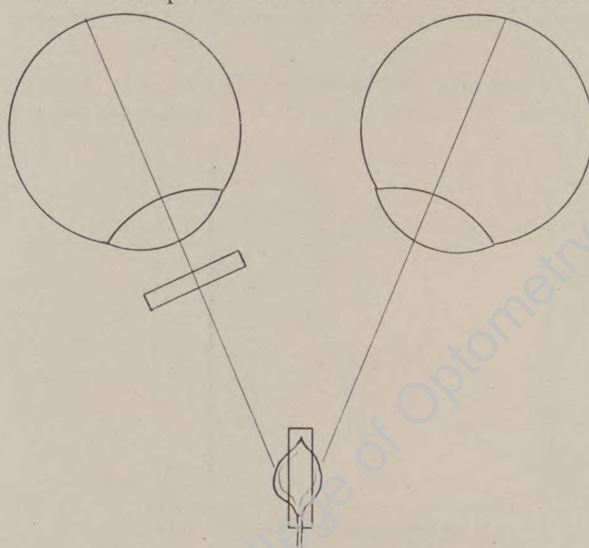
Illustrates the two dissimilar images as seen by the naked eye and through the Maddox rod.

strabismus, dependent upon the inability of the affected eye to accurately follow the convergent movements of the sound eye.

Maddox Rod.—A much more delicate and reliable test, however, is that furnished by the Maddox rod found in every trial case. This device is an opaque disc into which is set a cylindrical piece of colored glass, which is

mounted before the suspected eye, the other eye being left uncovered, and the patient instructed to look at a small flame six meters away.

The Principle of the Maddox Test is that

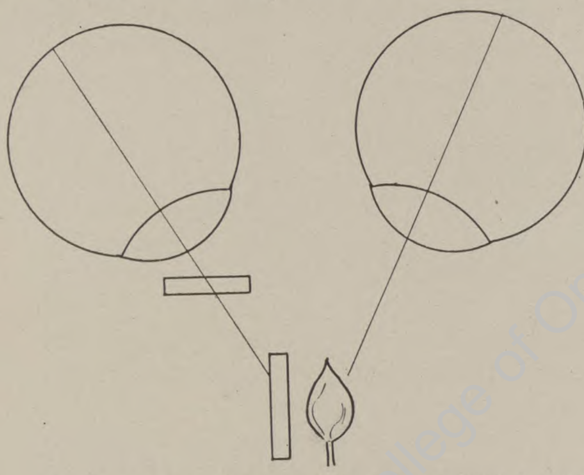


Illustrates the fusion of the images as seen by the normal eye with the Maddox rod.

the image of the flame on the uncovered eye is that of a round white flame, while on the covered eye it is drawn out into a long bar of colored light, thus dissociating the retinal conceptions of the image and lessening the desire for single vision.

If the muscles are in perfect balance the images on the two retinae will accord without effort and irrespective of the identity or difference of their form, and the round white flame will be seen with the rod of colored light running through it.

If there is muscular imbalance, the dissocia-

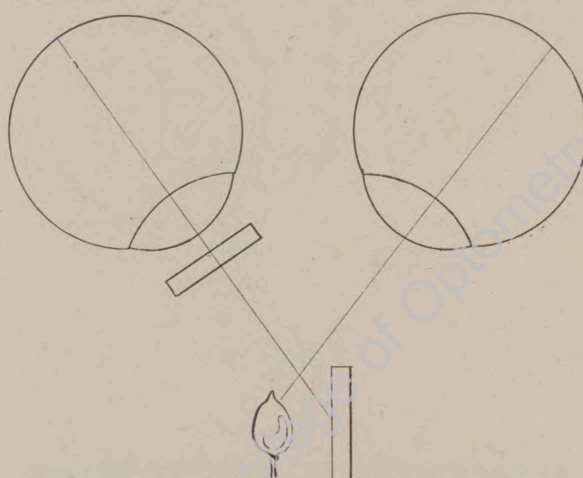


Illustrates the dissociated images as seen in convergent imbalance with the Maddox rod.

tion of the retinal images and the consequent weakening of the desire for single vision will induce the patient to give up his effort to preserve the single image; double vision will at be seen to one side of the white flame—on the once result, and the rod of colored light will

same side as the covered eye if the imbalance is convergent, on the opposite side if divergent.

Use of the Maddox Rod.—It is important that the disc containing the Maddox rod be placed exactly in front of the patient's pupil, otherwise it will entirely fail of its effect. It must also be remembered that as the rod is a



Illustrates the dissociated images as seen in digent imbalance with the Maddox rod.

cylinder it will draw out the flame into a bar precisely at right angles to the axis of the rod, and must therefore be placed before the eye at right angles to the direction in which it is desired that the bar of light shall

appear. In testing for convergent and divergent imbalance (the only two varieties here considered), it is desirable to have the rod appear vertical, hence the rod should be placed horizontally. In testing for hyperophoria, or imbalance of the obliques, the reverse is desirable. This form of imbalance, however, is rare, and has no direct relation to refraction.

Prism Test.—In cases of bilateral muscular insufficiency, which, of course, can hardly be regarded as imbalance, since both eyes are alike affected, the insufficiency is detected and measured by means of prisms, as described under Convergence.

Elimination of Refractive Errors.—As stated, every condition of ametropia is inherently attended by muscular imbalance, hence by the time the patient comes to the refractionist a part of the muscular trouble has become permanent, due to anatomical changes in the muscle, and a part of it is still an integral factor in the ametropia. After testing the amount of imbalance in the unaided eye, therefore, the operator should correct the error of refraction with appropriate lenses, and make another test, subtracting the result of the second test from that of the first to find the net amount of permanent imbalance which needs treatment.

Treatment of Imbalance.—If the degree of heterophoria is slight it is usually sufficient to correct the error of refraction, and when this cause of the trouble is removed the muscle will right itself. In severer cases, however, a course of optic exercises must be carried out, with prisms base in or base out as the case may demand, and as indicated by what has already been said. These exercises should be nicely graduated, and carefully supervised by the refractionist, and need to be persisted in with great constancy and patience. In cases of convergent imbalance the results are usually very satisfactory; in divergent imbalance they are less encouraging as there is no known stimulus for the unilateral contraction of the external rectus.

CHAPTER XIV.

SPECTACLES.

It is highly important that the glasses themselves be properly fitted to the patient's eyes, and the refractionist himself should attend to this feature of the treatment. Tabulated instructions are usually found on the prescription blanks issued by optical firms for the proper measurement of the frames, and these should be fully and carefully followed out in prescribing the glasses.

From an optical standpoint the most important things to be observed are:

1. That the size of the lens is sufficient to cover the eye. Optician's prescription blanks usually designate this by a graded scale of sizes, represented by 0, 00, 000, etc.

2. That the center of the lens is exactly opposite the visual axis of the eye. This is insured by a proper measurement of the width between the two pupil centers. For distance vision the lenses should then be made to stand perpendicularly; for near vision they should converge in accordance with the visual axis.

3. In myopia and astigmatism the lens should not be further than 13 mm. from the eye. Hypermetropes, and especially pres-

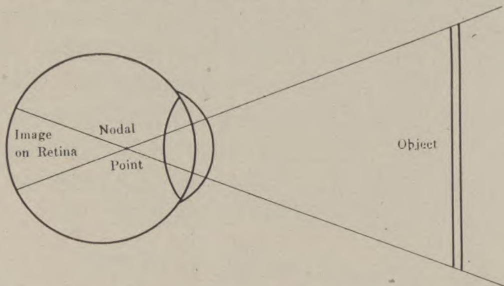
byopes, may generally suit their own comfort and convenience in this respect.

4. In astigmatism it is of course essential that the lenses always maintain the angle at which they are prescribed. To ensure this, it is always advisable that astigmatic patients wear bow-spectacles. However, there are now in the market very improved makes of eye-glasses that provide for this necessity, and these may be worn in selected cases. Care must be taken that they do not become bent and out of shape, for this spoils the tilt of the cylinder axis and defeats the purpose of the lens.

In hypermetropes, so long as No. 6 type can be read at 6 meters, the glasses need only be worn when near work is being done. If, however, even distant vision is defective, they should wear glasses to correct this. When hypermetropia is accompanied by strabismus (squint) full correction (latent and manifest) should be worn constantly.

Myopes whose myopia is of low degree may be given eye-glasses for use in distant vision, and be allowed to read and write without any glasses. In myopia of medium degree they should wear their full correction constantly. Myopes of high degree should have separate glasses for near and distant use, as recommended in the chapter on myopia.

Astigmatic patients should wear their glasses constantly. If the astigmatism is associated with high degrees of hyper-



Showing how the bringing forward of the nodal point in myopia enlarges the size of the inverted image on the retina.

metropia or myopia, necessitating separate glasses for near and distant use, the full correction of the astigmatism should be put into both pairs of glasses.

Showing how the carrying back of the nodal point in hypermetropia diminishes the size of the inverted image on the retina.

Diminishing Effect of Concave Lenses.—It should not be forgotten that convex glasses,

by bringing forward the nodal point, enlarge the visual angle and so increase the size of the image, and concave glasses, by carrying back the nodal point, decrease the visual angle and so diminish the size of the image.

This should be explained to patients, especially those wearing concave glasses, who are apt to complain that they do not see clearly with them, whereas the truth is they do not see as largely with them.

CARDINAL POINTS.

Always have a good light, if possible behind the patient, in making the type tests.

Always test each eye separately, by each method, excluding the other eye meanwhile by the opaque disc.

Always begin with convex lenses. They relax the ciliary muscle.

Never be satisfied with one kind of test. Confirm it with other methods.

Always paralyze the eye, if possible, in a patient under 30.

In patients over thirty years of age use homatropin and cocain.

Astigmatism in a young patient cannot be properly estimated without paralysis.

Look out for ciliary spasm. When the patient begins to get erratic in his replies—seeing first one thing and then another—stop

testing and insist upon atropin or use a convex lens.

Have a system and follow it out. Nothing weakens a patient's confidence and confuses the refractionist like aimless pottering.

Having carefully attended to the correction of the refraction, pay equally careful attention to the mechanical features of the glasses. They are of great importance, and often make just the difference between success and failure.

CHAPTER XV.

DISEASES OF THE EYE CONNECTED WITH DISTURBANCE OF VISION.

As a general proposition it may be stated that if, after a thorough and conscientious application of the methods herein set forth, the patient's acuity of vision is not improved, the trouble is due to other than refractional errors, and is a proper subject for medical or surgical attention. However, it is well to be able, as the examination proceeds, to recognize pathological conditions by the same agencies and means as are being used to detect errors of refraction, and with a little intelligent care this can be readily done.

A great many of the commoner diseases of the eye can be at least suspected, if not recognized, from unaided observation. More definite information can in many cases be obtained by means of the ophthalmoscope, and for this reason, if for no other, it is advisable that an objective examination be made of every eye that comes to one for correction. A very little intelligent practice will enable the observer to detect and identify abnormal conditions of the fundus seen through the mirror.

Following are some of the diseases of the

eye most commonly met with in connection with difficulties of vision, for which the patient consults the refractionist.

Simple Acute Conjunctivitis.

This occurs to a more or less extent in almost every ametropic eye, due to congestion consequent upon eye strain, and is the commonest trouble in the refractionist's experience. It is highly important that he be able to differentiate it from more serious and deep seated diseases.

Symptoms.—In its mild forms it is characterized by more or less injection of the ocular conjunctiva (i. e., the conjunctiva covering the eye-ball), itching and burning, sensation as of sand in the eye, stickiness of the lids, and sensitiveness to light. In its severer forms all of these symptoms are intensified, and the discharge, which is thick, is so profuse as to glue the lids together when closed for any length of time.

Diagnosis.—The characteristic feature about conjunctivitis is the superficiality of the congestion, as shown by the brick red color of the injected vessels, which run in a tortuous network, whose individual branches can be readily distinguished, and can be moved with the membrane. No other disease of the eye, producing injected vessels, shows this characteristically superficial set of conditions.

Treatment.—The milder forms, dependent upon errors of refraction, need only a correction of the latter to remedy the congestion. Cloths wrung out of cold water make a very grateful application. In the more severe forms the eye should be protected from the light, and a saturated solution of boric acid instilled at frequent intervals.

Chronic Conjunctivitis

Presents the same set of symptoms as the acute variety, but in more obstinate and subdued form. The lids and conjunctiva are usually thickened.

Treatment.—Daily instillations of astringent lotions, as tannic acid or nitrate of silver, 1/8 grain to the ounce, ointment of yellow oxid of mercury, and the application of copper sulphate stick once a week. Errors of refraction, if present, must be corrected, or a cure will never be effected.

Purulent or Gonorrheal Conjunctivitis

Rarely comes under the notice of the refractionist. It is a very virulent and rapid inflammation, due to gonococcus infection.

Symptoms.—Those of acute conjunctivitis, but in a most violent form, rapidly passing into profuse suppuration. Pain is intense, and extends to the surrounding parts. There is great swelling. The disease has been known to destroy an eye within twenty-four hours.

Treatment, which is urgent, should be undertaken only by a skilled oculist. The all-important factor in "first aid" is to promptly protect the sound eye, by as efficient a covering as possible, from possibility of infection.

Trachoma

Is a very dangerous and contagious form of follicular conjunctivitis, characterized by granular hypertrophy of the membrane and subsequent degeneration of tissue.

Symptoms.—Intense itching, burning, and pain, intolerance of light, profuse watery secretion (which is contagious), visual disturbance. The palpebral conjunctiva (i. e., the conjunctiva covering the lids) above and below is thickened and angry-looking, covered with coarse red granules, giving the eye a heavy appearance. There are no ophthalmoscopic phenomena.

Pannus.

A frequent result of trachoma, is a layer of newly-formed vascular tissue, overlying the ocular conjunctiva like an opaque skin.

Treatment requires considerable judgment and patience, and should be carried out only by an expert oculist. The milder forms may be relieved and even cured by applications of copper sulphate stick, or two percent nitrate of silver solution, but the more severe varieties usually need surgical attention.

Interstitial Keratitis

Is a not infrequent disease coming under the observation of the refractionist, and has to be carefully differentiated from conjunctivitis. It is an inflammation of the cornea.

Symptoms.—Gray, steamy condition of the cornea, injection of the vessels, watery secretion, intolerance of light, pain, interference with vision.

Diagnosis.—The characteristic feature about the congestion of keratitis is that the vessels involved are the deep ciliary vessels, not the superficial ones of the conjunctiva. The injection is therefore seen as a faint pink, the separate veins cannot be distinguished but appear as a set of regular parallel lines of color, and cannot be moved with the conjunctiva. The steamy appearance of the cornea, the pain, and the marked disturbance of vision further serve to distinguish it from conjunctivitis.

Treatment.—Protection from light, hot compresses and atropin to promote absorption. When the cornea begins to clear stimulating ointments, such as yellow oxid of mercury, but these must not be applied too early.

Iritis

Is an inflammation of the iris, usually due to some constitutional disease, such as syphilis,

rheumatism, tuberculosis, gout, diabetes, etc., but may arise from any cause.

Symptoms.—Pain, intolerance of light, watery secretion, disturbance of vision, the iris is dull and lustreless, the pupil contracted and irregular, owing to adhesions of the iris to the lens. The cornea is turbid and there is the characteristic pink ciliary injection. The pupil contracts very sluggishly.

Diagnosis.—The diagnostic features of iritis are the pain, the appearance of the iris, and the very marked dimness of vision. The pain is sharp and neuralgic, usually worse at night, and accompanied by tenderness of the eyeball, due to ciliary involvement.

Treatment.—Rest and protection from light. Leeches and hot fomentations to relieve congestion. Atropin, used to toleration, to dilate the pupil and thus prevent adhesions of the iris to the lens or break up those that already exist. Medication for the underlying disease.

Choroiditis.

Inflammation and degeneration of the choroid, which is really an extension of the iris.

Symptoms.—Dimness of vision, distortion of objects, spots before the eyes, flashes of light and circles, no pain.

Diagnosis.—There are no external phenomena, but the ophthalmoscope shows yellowish

white patches diffused over the fundus, with the retinal arteries passing over them. Later, when atrophy of the choroid begins, the atrophic areas show as white spots, and the disc frequently presents a yellowish white color.

Treatment.—The same as for iritis.

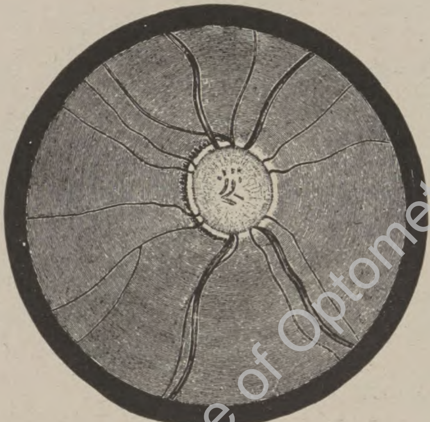
Glaucoma

Is one of the most insidious diseases of the eye, and most often mistaken for other conditions until too late to remedy. It is therefore highly important that the refractionist should be able to recognize it early. It is characterized by an increased tension in the eye-ball and may be secondary to some other ocular disease or primary.

Symptoms.—The first symptom is always dimness of vision, usually appearing in the form of a sensation of fogginess, with concentric rings around the object looked at. This is caused by cloudiness of cornea which can be observed if carefully looked for. The tension of the eye-ball is increased, and it is hard to the touch. The pupil is dilated, often oval, and contracts sluggishly. There is frequently ciliary injection. Accommodation is diminished, so that the patient always requires stronger lenses than are natural at his age. There is severe pain.

Diagnosis.—The diagnostic features are the

increased tension of the eye-ball, the peculiar aberrations of vision, the abnormal diminution of accommodating power, and the pain, which is steady in character. The ophthalmoscope shows the disc excavated; this is due to the intra-ocular pressure. This phenomenon is diagnostic of glaucoma.



Illustrates cupping of disc in Glaucoma, as seen with ophthalmoscope.

Treatment is purely surgical, and must be undertaken only by a skilled oculist.

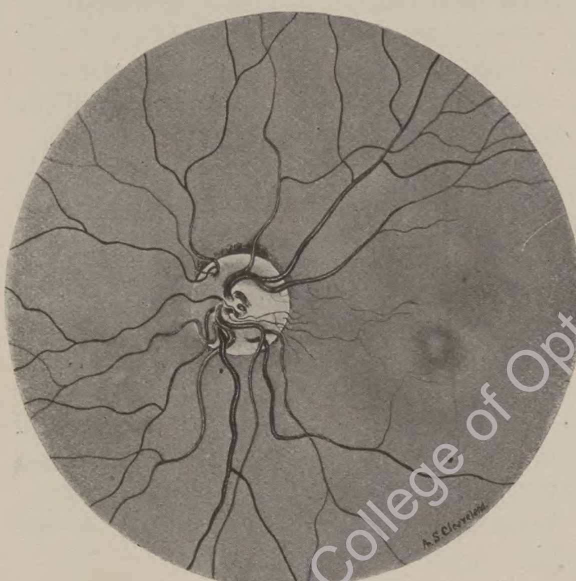
Retinitis.

An inflammation and degeneration of the retina usually due to constitutional diseases.

Symptoms.—Disturbance of vision, especially noticeable at night. Diminution of ap-

preciation of light. Pain is rare, but there is an uncomfortable feeling in the eyes. There may be intolerance of light.

Diagnosis.—There are no external signs. The ophthalmoscope shows the retina dull,



Illustrates appearance of fundus in albuminuric retinitis, as seen with ophthalmoscope.

the disc congested and indistinct, vessels tortuous and swollen, discrete or confluent white or yellow spots (exudations) diffused over the retina. In the retinitis of Bright's disease (re-

tinitis albuminuria) the white spots are arranged in star-shaped figures chiefly around the yellow spot.

Treatment.—Rest, protection from light and treatment of the underlying disease.

Detached Retina is characterized subjectively by disturbance of the field of vision, and the ophthalmoscopic phenomenon is that of a part of the retina missing from the field of the mirror. The treatment is purely surgical.

Optic Neuritis

(Choked Disc) is an inflamed condition of the optic nerve, due to some brain or constitutional trouble.

Symptoms.—Disturbance of vision. No pain.

Diagnosis.—The ophthalmoscope shows the head of the disc swollen and whitish in color, its margins indistinguishable and only recognized by the emergence of the vessels, which are themselves altered and interrupted.

Treatment.—Sheerly the treatment of the underlying lesion.

Optic Atrophy.

Atrophy of the optic nerve, due to affections of the nerve or the retina.

Symptoms.—Diminution of acuteness of vision, contraction of the field of vision, and eventual blindness.

Diagnosis.—By ophthalmoscope only. The

disc has a dense grayish white color, its minute vessels have disappeared, the arteries of the retina are small and the veins enlarged.

Treatment is unavailing.

As all of the ocular diseases above described are associated with disturbance of vision, either as the cause or result of the disease, the patient usually consults the refractionist first, with the idea that there is something wrong with his refraction, and it is therefore important that the refractionist should be able to recognize the conditions and acquaint the patient with the true nature of his trouble, so that he may secure the aid of a competent oculist without delay—for delays are serious in all eye diseases. A careful attention to the characteristic symptoms and appearances above set forth will very quickly enable any refractionist of ordinary intelligence and observation, who is on the lookout for possible pathological lesions, to detect and identify them.

CHAPTER XVI.

ASTHENOPIA.

Asthenopia is a broad term used to designate that group of symptoms which results from any form of eye strain due to functional causes, including that type of muscular and nervous exhaustion which has already been dealt with at length in the chapter on Muscular Imbalance. In a general way these symptoms are the same, from whatever specific cause they arise, and in the last analysis they are essentially reflex in their character, dependent upon an excessive and unequal innervation, and mediated primarily through the ocular and facial nerves.

Symptoms.—The primary symptoms common to all forms of eye strain are headache, smarting and watering of the eyes, twitching of the lids, spasm of the muscles, inability to use the eyes for any length of time, blurred vision after continued use, and in the severer forms neuralgic pains in the temporal and occipital regions.

Varieties.—As already stated, a common form of asthenopia is that which results from muscular imbalance, by reason of the unequal and excessive innervation performed by the

patient in order to preserve single vision. This type of the complaint is generally classified as **muscular asthenopia,** indicating that its anatomical and physiological seat is in the extrinsic ocular muscles, and is often due to prolonged work at near distance.

Myopia is also frequently responsible for this variety of asthenopia, on account of the extra amount of convergence that has to be exerted and the consequent straining of the internal recti muscles.

A second form of asthenopia, which really belongs to the muscular type, is that which arises from straining of the ciliary muscle in cases of hypermetropia or hypermetropic astigmatism. For the sake of distinction from that which depends upon the extrinsic muscles, however, this variety is usually known as **accommodative asthenopia.** It is by far the most common form of the trouble, because hypermetropia and hypermetropic astigmatism are by far the most common errors of refraction, and furthermore it is the type of asthenopia which gives most trouble to the refractionist, because the irritable and spasmodic condition of the ciliary muscle renders it almost impossible to obtain reliable results from the various tests by which he endeavors to detect and measure the refractive errors, almost all of which are

based upon the function of the accommodation. When such a condition exists, it usually evidences itself very quickly under examination by the patient giving erratic replies, seeing first one thing and then another, or by an excessively sensitive contraction of the pupil under illumination so that the observer cannot get a satisfactory view of the fundus, and in such cases it is necessary to either prescribe absolute rest of the eye for several days before continuing the examination or to paralyze the muscle with atropin or by a strong convex lens.

A third and rarer type of asthenopia is that which comes from sensitiveness or fatigue of the retina, due either to close and continuous work in bright light or over glittering materials or to constitutional diseases. This is called **retinal asthenopia.**

Remote Effects of Asthenopia.—Dr. Geo. M. Gould was the first to point out that the excessive or unequal innervation upon which all these forms of asthenopia depend can, and frequently does, extend its reflex influence to other organs and functions of the body. It is of course perfectly explicable, now that Dr. Gould has called attention to it, that the stimulus of these ocular nervous disturbances should, if powerful enough and long enough continued, react through the cerebral and

spinal centres upon the nervous tracts supplying the viscera and other parts of the body—so simple, indeed, that there is a tendency, as with all simple phenomena, to underrate the service that Dr. Gould has performed in recognizing the fact and making application of it.

Dr. Gould has shown that anorexia, dyspepsia, nausea, vomiting, constipation, dysmenorrhea, insomnia, chorea, nocturnal enuresis, and even epilepsy may result from long continued and severe eye-strain. Indeed, as he pertinently remarks, "the multiformity of the effects of eye-strain can only be properly realized when we understand how vital the function of vision is to every act, emotion, and thought."

Treatment of Asthenopia.—Broadly speaking, this consists in removing the cause. We have already outlined the method of dealing with those cases which depend upon muscular imbalance. Asthenopia due to errors of refraction can only be helped by careful and accurate correction of the error, and the vast majority of asthenopic patients obtain complete relief as soon as their refraction is made normal. The retinal types of asthenopia, and those which arise from abuse of an otherwise normal eye, will, of course, yield to nothing but a complete return to normal habits and

in severe cases a prolonged and thorough rest, enforced if necessary by the instillation of a mydriatic or the wearing of a strong convex lens.

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